PART II

PHYLOGENY, TAXONOMY, DISTRIBUTION, HABITS, AND ENVIRONMENT OF THE CERATOPSIA

BY

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PHYLOGENY, TAXONOMY, DISTRIBUTION, HABITS, AND ENVIRONMENT OF THE CERATOPSIA.

GENERIC AND SPECIFIC SUMMARY.

GENERAL DISCUSSION OF THE PHYLOGENY.

Of the fourteen genera which have at sundry times and by various authors been referred to the Ceratopsia but seven have survived the process of elimination to which they have been subjected. Of these, three more primitive genera were found in the earlier Judith River beds, and the remaining four, which are much more specialized, were found in the Laramie deposits. That there is a genetic relationship between the earlier forms and their successors is evident, and, as Osborn, Lambe, and Hatcher have suggested, there seem to have been at least two lines of descent, one leading to *Triceratops*, with its entire bony frill, and the other to *Torosaurus*, with persistently open parietal fontanelles.

Professor Osborn's[a] statement is as follows:

It is not at all improbable that the horned dinosaurs will prove to be diphyletic, one line, with persistent open fossæ, leading from *Monoclonius* to *Torosaurus*, the other leading to *Triceratops* with closed fossæ.

Lambe,[b] in speaking of the parietal of *Ceratops* (*Monoclonius*), says:

The parietal is about one-third the size of that of *T. gladius*, and would probably represent a proportionately smaller animal, an earlier and more generalized form of the genus, with larger fontanelles than its later Laramie successors.

In Hatcher's unrevised description of the genus *Torosaurus* (p. 150) he says:

As already remarked, the parietals of the present genus most nearly resemble the same elements in the type of *Monoclonius* (*M. crassus*), and there seems but little doubt that the last-mentioned genus was ancestral to *Torosaurus*.

In the revised portion of his manuscript, however (p. 100), Hatcher reverses this earlier decision in the following statement:

The affinities of *Monoclonius*, as shown in the type species, *M. crassus* Cope and *M. dawsoni* of Lambe, are apparently with the later genus *Triceratops* of Marsh, while *Ceratops montanus* Marsh, *C. recurvicornis* Cope, *C. canadensis*, and *C. belli* Lambe would seem to be ancestral to *Torosaurus*.

Mr. Lambe's statement is fully in accord with this, while that of Professor Osborn may be reconciled to it if by "*Monoclonius*" he had special reference to *M. canadensis* and *M. belli*, which Hatcher has removed to the genus *Ceratops*. If, on the contrary, Osborn had in mind the type species, *Monoclonius crassus*, his opinion as expressed would be at variance with Hatcher's final idea of these relationships.

The weight of evidence to be reviewed below is certainly in favor of Hatcher's final theory, according to which the genera may be provisionally arranged in two phyla in the following sequence:

Phyla of the Ceratopsia.

Geological horizon.	Triceratops phylum.	Torosaurus phylum.
Denver beds.	Triceratops.	
Laramie of Converse County, Wyo.	Diceratops. Triceratops.	Torosaurus.
Laramie of Black Buttes, Wyo.	Agathaumas.	
Judith River (Belly River).	Centrosaurus. Monoclonius.	Ceratops.

[a] Contr. Canadian Pal., vol. 3 (quarto), pt. 2, p. 31.

[b] Ibid., p. 67.

Of the two most primitive genera *Monoclonius* seems to be the more generalized and represents the earliest known stage in the evolution of the Ceratopsia. Because of the gap between the Judith River beds and those of the Laramie the series is by no means complete, nor are we yet aware of the characteristics of pre-Judith River ancestors. The earliest known Ceratopsia are endowed with the main distinguishing characters, the horns and parietal crest.

With the exception of the genus *Agathaumas,* of which the skeleton only is known, the more important taxonomic characters are found in the cranium, and the genera can readily be differentiated without recourse to the skeletal features; in fact, in four out of the seven genera these are unknown.

REVISION OF GENERA.

Taking the six genera recognized by Hatcher and one erected later by Lambe, which Hatcher would undoubtedly have accepted as valid, the main generic comparisons and contrasts are as follows:

I. THE MONOCLONIUS-TRICERATOPS PHYLUM.

1. *Monoclonius,* the most primitive genus, is comparatively small, and has three horn cores, the nasal being long, powerful, and curved backward. The supraorbitals are diminutive, flattened on the outer surface but very convex on that toward the median line, so that the basal section is almost triangular. The horns are sharp pointed. The orbit is nearly circular and in at least one species has a heavy rugose border. The frill is made up largely of the coalesced parietals, the squamosals being somewhat triangular, plate-like bones, short and proportionately broad. The margin of the crest is crenulated, but the prominences do not seem to have arisen from separate ossifications, as in the succeeding genera of this phylum. The parietals are widely fenestrated—in fact, they do not entirely surround the fenestræ, and the median bar is broad and thin in contrast to the much narrower bar in *Ceratops.* Of the skeletal characters those of greatest taxonomic value are found in the sacrum. The number of coalesced vertebræ in the entire sacrum is ten; of these eight bore sacral ribs, of which four pairs united distally on either side into a longitudinal bar for the support of the ilium. The centra were of medium length, constricted medially, and the sacral ribs arose directly opposite the points of articulation, so that each rib bore equally on two contiguous centra. The ilium is rather long and slender, and the deflected margin posterior to the ischiac peduncle is produced into a somewhat angular prominence. The blade is rounded anteriorly, while posteriorly it is elongate and narrows presumably to a point, though the extremity is not preserved. The blade, when the bone is in position, is horizontal, as in other Ceratopsia. In contrast with the ilium of *Agathaumas* that of *Monoclonius* is smaller and proportionately more slender, and the deflected external margin is more pronounced.

2. *Centrosaurus.*—In *Centrosaurus* the nasal horn is straight, laterally compressed so as to be lenticular in section, and somewhat similar to that of *Monoclonius sphenocerus.* The coalesced parietals entirely surround the large, oval fontanelles and the median bar is very heavy, especially between the peculiar inward-curved processes at its posterior border, but thins perceptibly toward the anterior portion of the frill. On either side the fontanelle is inclosed in a thin extension of bone. In addition to the two curved posterior prominences there are seven others, separated by emarginations, the posterior ones bearing separately ossified epoccipital bones as in *Triceratops.* The squamosals are short, as in *Monoclonius,* being confined to the antero-external angles of the frill.

3. *Agathaumas.*—The genus *Agathaumas,* so far as known from skeletal fragments, is intermediate in character between *Monoclonius* and *Triceratops.* It comes from the lower Laramie, near Black Buttes Station, Wyoming. In *Agathaumas* the main distinctive characters are of necessity derived from the sacrum, the ilia, the dorsal vertebræ, and the ribs. The sacrum has five true sacral vertebræ, probably with one presacral and four caudals, making ten in all, as in *Monoclonius.* In the type specimen, which was not fully mature, there are four pairs of sacral ribs, arising more directly from the articulations than in *Triceratops,* yet, with the exception of the first, not so much so as in *Monoclonius,* being in a condition

transitional between that in each. The four sacral ribs coalesce distally to form the horizontal bar for articulation with the ilia, but in the present instance the bar of each side is not continuous, the ribs being, as Cope expresses it, united in pairs. It is possible that continuity would have come later in life had the creature reached maturity. The centra of the true sacrals decrease in size regularly from first to last, as in *Monoclonius* and *Triceratops*, the first and second being particularly broad and short. They are somewhat more elongate than the dorsal centra, the vertical and transverse axes being more nearly equal. Perhaps the most important distinction is the point of origin of the sacral ribs. There was evidently a pleuro-diapophysial connection with the ilium, as in *Monoclonius* and *Triceratops*, but the diapophyses are not preserved. The dorsal vertebræ exhibit no marked distinction from those of the other genera.

In *Agathaumas* the blade of the ilium is much extended fore and aft, the anterior end being truncated and the hinder extremity narrow and elongate. The external margin is moderately thick throughout its length and much thicker near the extremities and in the deflected region above the ischiac peduncle. The internal margin is thin except in the region of articulation with the sacral diapophyses. A broad, convex ridge of bone extends diagonally across the anterior blade of the ilium to its antero-external angle, inclosing in front a deep depression just external to the acetabulum.

The ilium is actually larger and relatively shorter and broader than that of *Monoclonius*, and the deflection of its external margin is less pronounced. It differs from the ilium of *Triceratops* in being more slender and in having occasional thickenings of the external border, whereas in *Triceratops* the margin is more uniformly thin. The posterior end of the *Agathaumas* ilium is thin, while that of *Triceratops* is thickened.

The ilium of *Agathaumas* is transitional between those of the contrasted genera in general proportions, especially the relative length and breadth.

4. *Diceratops*.—This genus is known from a complete skull and, although unquestionably related to the *Monoclonius-Triceratops* phylum, its serial order is somewhat difficult to conjecture. By the absence of a nasal horn core it resembles *Triceratops obtusus*, though evidently not synonymous therewith. The fenestrated parietals would seem to point to primitive conditions until one notes the presence of similar fenestræ[a] in the squamosals, a character which here appears for the first time. This, together with the fact that the squamosal fenestræ are of unequal size—which may also have been true of those of the parietals, as only the right is preserved—leads one to conjecture whether they may not have been secondarily acquired and together with the vestigial nasal horn, may not be evidences of high specialization from some Triceratops-like ancestor. The main diagnostic characters wherein *Diceratops* differs from *Monoclonius* are the reduced nasal horn, the vastly increased supraorbital horns, the elliptical orbit, the well-developed parietals with their small fontanelles(?), the more elongate fenestrated(?) squamosals, and the separately ossified epoccipital bones.

From *Triceratops*, its nearest ally, it may be distinguished mainly by the much smaller rostral bone; by the absence of the nasal horn, which in all of the species of *Triceratops* except *T. obtusus* is fairly well developed; by the very erect, short, robust supraorbital horn cores, which seem to take their origin much farther back with relation to the orbit; by the concavity of the frontal region between the orbits; and, finally, by the peculiar form of the persistent postfrontal (pineal) fontanelle suggestive of that of the genus *Torosaurus*. The parietals are Triceratops-like except for the small fenestræ on either side of the median line, while the squamosals, aside from the unique fenestræ, differ from those of *Triceratops* in the conformation of the inferior border, which lacks the quadrate notch. Another distinctive feature is in the very erect position of the descending process of the jugal, which is directed slightly forward instead of downward and backward as in *Triceratops*.

[a] The writer is now firmly convinced that all of these apertures through the frill of *Diceratops* are pathologic, having been caused either by wounds or by disease (Am. Jour. Sci., 4th ser., vol. 20, pp. 419-422). Similar perforations occur in the right frontal of the type of *Triceratops serratus* (p. 124) and in the squamosal of that of *T. elatus* (p. 136). Mr. C. W. Gilmore, who prepared the type, is not sure of the parietal perforation, but as no bone adhered to the matrix at that point the opening was allowed to remain.

5. *Triceratops* (including *Sterrholophus*).—In *Triceratops* this phylum reaches its culmination in specialization and size, including some most formidable species.

The supraorbital horns reach their maximum development in *Triceratops,* while the nasal horn is in process of reduction and the broadly expanded frill, though not so large actually or relatively as that of *Torosaurus,* was much more efficient for protection because of its vastly greater strength.

The rostral bone is better developed than in *Diceratops,* being especially heavier in older individuals, and there is generally a sharp cutting edge on its inferior face. The nasal horn, while tending to reduce, is of moderate length in the more generalized species and is directed forward, so that its posterior face rises but little above the level of the upper surface of the nasal bones, in sharp contrast to that of *Monoclonius.* The nasal horn core is generally very rugose. The supraorbital horn cores are slender to robust, ovate in section as contrasted with the triangular cross section of the rudimentary horn cores in *Monoclonius* and the nearly circular section of those of *Diceratops.* In *Triceratops* the horn cores point upward and forward at an angle of 45°, whereas in *Diceratops* they are nearly erect. They range in length from short in *T. brevicornus* to very long in *T. calicornis.* The orbit is generally elliptical in shape with the long axis somewhat diagonal, running from above downward and forward, therein agreeing with *Diceratops* rather than with *Monoclonius.*

The parietals are convex laterally and somewhat concave along the long axis, much expanded posteriorly, but narrowing toward the forward end. They are thick along the more or less elevated and rugose middle line and around their posterior border, but very thin in the center of each side, though there are no traces of fontanelles. It is mainly in this last feature that the parietals differ from those of the other genera. The squamosals are stout and broad, constituting at least half of the area of the frill. The superior surface of the frill, and, in some aged individuals, the margin of the lower side as well, bears vascular impressions, showing it to have been sheathed in a horny covering. These impressions are much more pronounced than in either *Monoclonius* or *Centrosaurus.*

Hatcher has made no final disposition of the genus *Sterrholophus* either in his completed manuscript or in his notes, but one is justified in the assumption that he believed the genus to be synonymous with *Triceratops* on the ground that all of the distinctive features which would serve to separate the genera he considered as juvenile characteristics.

The type consists of disarticulated skull and other skeletal portions of an immature individual and differs from a typical specimen in the entire absence of vascular impressions from the frill. Those on the under surface are seen only in aged individuals, as in the type of *Triceratops prorsus* (Pl. XXXIII), and it may well be that their appearance on the superior surface of the skull is a strictly adult feature.

Another distinction between the skulls of *Triceratops horridus* and *Sterrholophus flabellatus* is shown in figs. 9 and 27, pages 18 and 30. In the former the olfactory foramina are paired, whereas in the latter there is but a single foramen. But, as Hatcher says, "it is probable that the median septum was present as cartilage and was lost in maceration. It is very unlikely that there was in any of these dinosaurs a single olfactory nerve." Another distinction between *Sterrholophus flabellatus* and some species of *Triceratops* is in the position of the lachrymal foramen, which is entirely within the maxillary, not as in other species between the maxillary and nasal. In this feature *Triceratops prorsus* agrees with *Sterrholophus flabellatus,* while in *T. serratus* the other condition obtains, *T. brevicornus* having the foramen between the nasals and maxillary but embraced by an ascending process of the maxillary in its anterior moiety, a condition transitional between that of the other two. This character can thus be considered of specific value only. It would therefore seem wise, in the light of our present knowledge, to consider the newer generic name *Sterrholophus* as a synonym of *Triceratops.*

The main skeletal comparisons between *Triceratops, Agathaumas,* and *Monoclonius* which it is possible to make lie in the sacrum and ilia, in which *Triceratops* shows a further advancement over *Agathaumas.* The general structure of the sacrum agrees with that of the latter in having ten vertebræ. Of these four bear sacral ribs, which coalesce to form the longitudinal

bar for articulation with the ilium. The first pair of ribs agrees with those of both above-mentioned genera in springing from the point of articulation between vertebræ 2 and 3, bearing equally upon each, while the succeeding sacral ribs arising *behind* the articulation bear very little upon the preceding centrum at all. A reference to figs. 53 and 77 (pp. 52 and 75) and Pls. X and XXV (pp. 218 and 248) will make clear these comparisons and contrasts.

The ilium in *Triceratops* is broad and elongated, much expanded anteriorly and tapering to a somewhat thickened point behind, whereas in *Agathaumas* the posterior extremity is thin. The external border is thin and smooth in contrast to the variably thickened margin in the latter genus. The outline as viewed from above is less regular than in *Agathaumas*, which is due to a greater prominence of the deflected border above the ischiac peduncle. In *Triceratops* the internal margin is greatly thickened, forming the superior border of the acetabulum and strengthening the peduncles. Compare figs. 55, 61, and 82.

II. THE CERATOPS-TOROSAURUS PHYLUM.

Of the second phylum but two genera are as yet known, *Ceratops* and *Torosaurus*, agreeing in the possession of large, persistently open parietal fenestræ and in the general conformation of the squamosal, which, while not so saber-like in *Ceratops* as in *Torosaurus*, exhibits a strong tendency to become so, in sharp distinction with the short, broad, triangular squamosals of *Monoclonius*.

The members of this phylum also agree in the absence of separately ossified epoccipitals, the crenulated effect of the margin of the frill being produced by prominences which do not arise as separate ossifications. An exception to this is found in the type specimen of *Ceratops* (*Monoclonius*) *recurvicornis* Cope, referred to *Ceratops* by Hatcher but possibly representing a new genus, a member of the *Triceratops* phylum.

1. *Ceratops*, a Judith River genus, is known only from portions of the skull, no other skeletal elements having been discovered. Our knowledge of the nasal horn core is imperfect, as it is derived only from the specimen of *Ceratops recurvicornis* mentioned above. In this specimen the horn core is massive, compressed distally, and curves forward instead of backward, as in the contemporary genus *Monoclonius* (see fig. 3). Another isolated horn core, figured in Lambe's memoir (Pl. XVII, fig. 1=Pl. XVIII, fig. 1 of this monograph), was referred by that author with a query to *Monoclonius dawsoni* Lambe. Hatcher claims that it curves forward instead of backward, which would seem to place it in the genus under consideration, though under what species can not be determined.

The supraorbital horn cores show a greater degree of development than in *Monoclonius*, but are apparently still smaller and less massive than the nasal core. They are more nearly circular in cross section, being subtriangular near the base, and are curved forward and upward and, in one species, *C. montanus*, strongly outward (fig. 103).

The orbit is oval, with its long diameter nearly vertical as contrasted with the circular orbit of *Monoclonius* and the more nearly horizontal oval of *Torosaurus*.

The coalesced parietals are reduced to a slender, median bar, subcylindrical in mid-length, and narrow postero-lateral processes, which only partially surround the large elliptical fontanelles.

The squamosals, which overlap the outer portions of the parietals, are triangular and more elongate than in *Monoclonius*, tending toward the form of squamosal found in *Torosaurus*.

2. *Torosaurus*.—The proportions of the *Torosaurus* cranium at once separate it from that of any other genus, especially from its immediate contemporaries, for while in *Triceratops* the frill and facial region are well balanced, in *Torosaurus* the huge crest entirely overshadows the abbreviated anterior portion of the skull.

The nasal horn core in the type species is broad at the base and the sharp apex is directed upward and forward. The supraorbital horn cores are larger, as in all Laramie Ceratopsia, and ovate in basal section, with the broader end of the oval to the rear. The cores are directed upward, outward, and forward. Thus the nasal horn core is relatively smaller while the supra-

orbitals are larger than in *Ceratops*. The orbits are elliptical, with the long diameter more nearly horizontal than in other genera, and are placed farther forward relative to the position of the horns than in *Triceratops,* while the skull is broad and massive between them, narrowing very rapidly toward the snout. The skull is extremely broad in the region beneath the orbits, as the external surface slopes downward and outward as compared with the more nearly vertical sides of the skulls referable to the genus *Triceratops*. There is a large lachrymal foramen well in advance of the orbit.

The postfrontal fontanelle seems to have been paired, at least in *T. latus*, the type of *T. gladius* being too imperfect to permit one to judge. From this run two shallow grooves directed outward and backward, each ending in a small foramen. There are similar grooves in the type of *Diceratops*, and in the specimen (Nos. 1203 and 1206–1210, U. S. National Museum) referred by Marsh to *Triceratops sulcatus* (Pl. XXXVII, fig. 1) the grooves are present but as the posterior portion of the skull is broken away the terminal foramina can not be seen. In each of these forms, however, the postfrontal foramen is unpaired.

The parietals are broad and long, with large supratemporal fontanelles. The parietal fontanelles are not so large proportionately as in *Ceratops*, and the median bar is broad, thin, and smooth, especially toward its posterior end. The squamosals are very elongate and swordlike, readily derivable from such as are found in *Ceratops*. The quadratojugal notch is much less pronounced than in *Triceratops;* the groove for the quadrate being far in advance of its position in other genera. The posterior margin of the frill is emarginate, but there are no separately ossified epoccipitals as in *Triceratops*.

III. GENERA ELIMINATED OR REMOVED FROM THE CERATOPSIA.

The genera abandoned or removed from the Ceratopsia by Hatcher are named below:

1. *Claorhynchus* Cope, with its one species, *trihedrus,* founded upon a rostral and predentary bone, and now lost sight of, Hatcher supposes, from Cope's description, to pertain to the Trachodontidæ rather than to the Ceratopsia.

2. *Dysganus* Cope, with its four species, *D. encaustis*, *D. haydenianus*, *D. bicarinatus*, and *D. peiganus*, is abandoned on the ground that it was "based on teeth pertaining to two or more genera belonging in part to the Trachodontidæ and in part to the Ceratopsidæ." The type material was very imperfect and the descriptions were inexact and unaccompanied by figures, hence the genus should, in Hatcher's opinion, be considered a nomen nudum.

3. *Manospondylus* Cope, with its single species, *gigas*, is based upon the centrum of a single vertebra (fig. 105). From its general form, its coarsely cancellated internal structure, and the deep fossa of the superior lateral surface it resembles most closely the vertebræ of *Dryptosaurus*, a theropod dinosaur, hence one is justified in removing the genus in question from the Ceratopsia.

4. Another of Cope's genera, *Polyonax*, with the species *mortuarius*, erected upon "fragments of horn cores, vertebræ, etc.," is abandoned because of "the extremely fragmentary and totally inadequate nature of the material upon which the genus and species are based."

5. Finally, Lambe's genus *Stegoceras*, with its single species, *validus*, is based upon two cranial fragments (figs. 99 and 100 and Pl. XXII), which Lambe called "prenasals," but which Hatcher believed are the "superior portion of the occipital, parietal, and frontal segments of the skull" of a reptile which may represent an order new to science. He further adds that "there is no good reason for considering them as horn bearing or the animals to which they belonged as pertaining to the Ceratopsia." Hence Hatcher does not include the genus in that group.

6. *Sterrholophus* Marsh is considered synonymous with *Triceratops*, for the reasons already mentioned.

REVISION OF SPECIES.

I. THE MONOCLONIUS-TRICERATOPS PHYLUM.

MONOCLONIUS.

Of the seven species referred to the genus *Monoclonius* by their several authors, Hatcher retains but three, *M. crassus* Cope, *M. dawsoni* Lambe, and *M. sphenocerus* Cope. He abandons *M. fissus* Cope, because of insufficient type material, while the remaining three, *canadensis* Lambe, *recurvicornis* Cope, and *belli* Lambe, are removed to the genus *Ceratops*.

1. *Monoclonius crassus* Cope (pp. 71–80, figs. 75–88) is the type species and is known from the remains of at least two individuals (type No. 3998, American Museum of Natural History), including the parietals, the frontal and postfrontal bones, a supraorbital horn core, and other portions of the skeleton. Of this material only that pertaining to the skull can be used in specific contrast, for of the remaining species no skeletal parts are known.

The supraorbital horn core (fig. 76) is low, broad below, and pointed above, with a flat outer face and a strongly convex inner surface. The main point of contrast with that of *M. dawsoni* seems to be one of size, as in the latter the horn cores are extremely diminutive, so small, indeed, as to have been overlooked by so careful an observer as Lambe. The orbit is nearly circular, with a thick, rugose border.

The complete parietals (fig. 75) are known only in this species, though fragments of parietals included in the type specimen of *M. dawsoni* show no specific distinctions from those of the species under consideration.

As the parts preserved in *M. crassus* are unknown in *M. sphenocerus* one can not contrast them.

2. *Monoclonius dawsoni* Lambe (pp. 89–93, fig. 92) is known from cranial fragments of specimen No. 1173, Geological Survey, Canada. The second specimen, consisting of parietals and a nasal horn core (No. 971), referred to by Lambe in his original description, has been made the type of a new genus and species, *Centrosaurus apertus* Lambe, in a paper published[a] since Hatcher's death (see p. 93, footnote *b*).

The nasal horn core is large, somewhat compressed, backward curving, and ovate in section, with the broader end in front, differing materially in shape from that of *M. sphenocerus*. The supraorbital horns are described as very diminutive and triangular in section, as in *M. crassus*. About 1 inch of the apex is not preserved.

The parietals are known only from a fragment with four marginal undulations, as in *M. crassus*.

The orbit is large and circular. Both orbit and nasal horn core are very large in proportion to the occipital condyle, maxillaries, and quadrate. Hatcher was "inclined to regard the present species as closely allied to if not identical with *M. crassus* of Cope." Some of the remainder of the material provisionally associated with the type by Lambe, consisting of a sacrum, a scapula and coracoid, a predentary, and a rostral bone, may pertain to other genera and species.

3. *Monoclonius sphenocerus* Cope (pp. 87–88, fig. 91, A, B, C) consists of portions of premaxillary, nasals, and nasal horn of a large though scarcely adult animal. It is distinguished from *M. dawsoni* in the form of the nasal horn, which is much compressed, with the anterior margin acute and the posterior rounded, the reverse of that of the last-mentioned species. In *M. sphenocerus* the horn is straight and directed upward and backward instead of being curved backward, as in *M. dawsoni*. It is, as Hatcher says, the largest and most powerful nasal horn core observed in any of the Ceratopsidæ (fig. 91). Thus *M. sphenocerus* is in sharp contrast with *M. dawsoni*, and probably also with *M. crassus*, though a direct comparison with the latter can not be made. The nasal horn resembles most closely the one associated by Lambe with the parietals which constitute the type of his new genus *Centrosaurus*, and the true affinities of *M. sphenocerus* may prove to lie with that genus.

[a] Ottawa Naturalist, vol. 18, 1904, pp. 81–84. This paper was issued July 7, four days after Hatcher's death.

CENTROSAURUS.

1. *Centrosaurus apertus* Lambe (p. 93, footnote *b*; fig. 93; Pl. XXIV) is based upon a parietal crest and an associated nasal horn core (No. 971, Canadian Geological Survey), and no specific distinctions need be reviewed.

AGATHAUMAS.

In the genus *Agathaumas* Hatcher retains but one species, *A. sylvestris* Cope, the other, *A. milo* Cope, having been referred later by its author to *Hadrosaurus occidentalis*. Hatcher sums the matter up by adding: "Whether or not this determination was correct the fact remains that *A. milo* is a nomen nudum, and the fragmentary nature of the type precludes adequate description. The species should therefore be discarded."

1. *Agathaumas sylvestris* Cope.—The characteristics of *Agathaumas sylvestris* (pp. 105–111, Pl. XXV) have been discussed under the generic summary.

DICERATOPS.

1. *Diceratops hatcheri* Lull.—This genus contains but one species, *D. hatcheri*, described but left unnamed by Mr. Hatcher, based upon skull No. 2412, U. S. National Museum (p. 149, Pls. XLVII and XLVIII). The specific characters need not be cited in this summary, but one species being thus far known.

TRICERATOPS.

The present writer recognizes ten species under the genus *Triceratops* Marsh, a number which he believes to be in harmony with Hatcher's views, though in the case of *T.* (*Sterrholophus*) *flabellatus* no final statement by Hatcher has been found.

These species are as follows:

1. *T.* (*Ceratops*) *horridus* Marsh.
2. *T. prorsus* Marsh.
3. *T. brevicornus* Hatcher.
4. *T. serratus* Marsh.
5. *T.* (*Bison, Ceratops*) *alticornis* Marsh.
6. *T. sulcatus* Marsh.
7. *T. elatus* Marsh.
8. *T. calicornis* Marsh.
9. *T.* (*Sterrholophus*) *flabellatus* Marsh.
10. *T. obtusus* Marsh.

Thus three species have been brought into the genus, two from *Ceratops* and the only species of *Sterrholophus*, which becomes synonymous with *Triceratops*. One species, *T. galeus* Marsh (p. 132, fig. 111), which was based upon a single horn core that resembles most the same structure in *Torosaurus gladius*, Hatcher decided to abandon on the ground of the fragmentary nature of the specimen.

1. *Triceratops horridus* Marsh (pp. 117–122, figs. 24, 25, 27, 107, Pl. XXVI), the type species, is based upon the imperfect skull of a huge individual, No. 1820, Yale Museum, fully adult and very old.

The rostral bone is very heavy, not so sharp along its inferior border as in some species, downward curved toward the tip, with deep vascular impressions.

The nasal horn core (Pl. XXVI) is very broad at the base, short and blunt in contrast to that of the most nearly allied species, *T. prorsus*, in the type of which the nasal horn is long and directed forward, and *T. brevicornus*, in which it is short and very stout but not highly rugose. This contrast is the more interesting because the types of all three species were aged individuals.

The supraorbital horns in *T. horridus* are exceedingly stout and rugose, long, and directed forward as in *T. prorsus*, in contrast to the extremely short horns of *T. brevicornus*. The great size of *T. horridus* as compared with either *T. prorsus* or *brevicornus* is an important distinction.

2. *Triceratops prorsus* Marsh (pp. 127–132, figs. 35, 37, 40, 41, 49–58, 63–67, 71, 109, 110, Pls. VI–XVII, XXX–XXXVI) is an example of the opposite extreme in size from *T. horridus*, the type skull, No. 1822, Yale Museum, that of an aged individual, being one of the smallest of the Laramie Ceratopsia.

The rostral bone is contrasted with that of *T. horridus* in being somewhat less massive and having a sharp cutting edge, as contrasted with the blunt margin in the other. The inferior margin curves downward toward the point, in agreement with *T. horridus* and *T. brevicornus*.

The nasal horn core is long and is directed forward, the anterior border extending forward and upward at an angle of 30° instead of being perpendicular to the long axis of the skull as in *T. horridus* and *T. brevicornus.* The horn much exceeds that of each of the contrasted species in length, the tip of the horn in the type specimen being just over that of the rostral bone (Pl. XXXIV).

The supraorbital horn cores are slender, and are directed upward, forward, and outward at an angle of 45° for about half their length, then curve gently inward. Here the contrast with the allied species is evident in the stoutness of the horns as compared with their slenderness in *T. prorsus.* The horns of *T. prorsus* are much longer proportionately than those of *T. brevicornus.*

The orbits in the present species are nearly circular as contrasted with the elliptical orbits of *brevicornus.* The form of those of *T. horridus* can not be ascertained, as but a quarter of the margin is preserved, but they would seem to agree more nearly with those of *T. prorsus.*

The lachrymal foramen is entirely within the maxillary bone, as in *T.* (*Sterrholophus*) *flabellatus,* in contrast to its position between the maxillary and nasal as in *T. serratus*, *T. brevicornus* being in a sense transitional between the two types, while the condition which obtained in *T. horridus* can not be determined, as this part of the specimen is lacking.

The frill is deeply arched transversely, ranging through an arc of 27°, with seven lateral and one median epoccipitals, making fifteen in all. The quadratojugal notch is deeper than in any other known species, and the postfrontal (pineal) fontanelle is entirely closed. Posteriorly the frill border was free, for vascular impressions occur on its inferior face for a distance inward of 20 cm. from the margin. This feature, together with the closure of the postfrontal fontanelle, may be a characteristic of old age, but in some old skulls of other species the fontanelle seems to be persistently open.

3. *Triceratops brevicornus* Hatcher (pp. 141-142, Pls. XL–XLII) presents another instance of an aged individual, the type being No. 1834 of Yale Museum.

The rostral bone is proportionately very heavy, with a deeply excavated inferior surface. The nasal horn core is short and very stout, the antero-posterior diameter much longer than the transverse, and the anterior border vertical, as in *T. horridus.*

The supraorbital horn cores are short and stout and, in contrast to the much longer cores of *horridus* and *prorsus*, more nearly circular in section than in any other species.

The orbit is an irregular ellipse, and the lachrymal foramen lies between the nasal and maxillary bones, but is partially embraced by an ascending process of the latter.

The infratemporal arcade is formed from the quadrate, with overlapping processes from the jugal and squamosal, as in *T. serratus.* The frill is elevated somewhat sharply toward the posterior margin, as in *T. prorsus*, and bears nineteen epoccipitals, six pairs of which are borne on the squamosals, as contrasted with fifteen in the last-named species. It is doubtful whether or no this will prove a specific rather than an individual distinction (Hatcher).

4. *Triceratops serratus* Marsh (pp. 122-127, figs. 16, 26, 32, 34, 42, Pls. XXVII–XXIX) is founded upon the skull of an immature individual (No. 1823, Yale Museum), but one in a remarkable state of preservation.

The rostral bone is rather small, lighter and less rugose than in other species; this, however, may be either a juvenile or possibly a sexual character.

The nasal horn core is wanting in the type, having been lost at the suture between it and the nasals. It must, however, have been considerably compressed transversely.

The supraorbital horn cores are slender and much more erect than in most species, somewhat elliptical in section at the base and more nearly circular in their mid-length.

The orbit is large and irregularly elliptical in outline, its long axis running obliquely downward and forward. The position of the orbit is in advance of and superior to that of *T.* (*Sterrholophus*) *flabellatus.*

The lachrymal foramen lies between the nasal and maxillary, as in the last-mentioned species.

The general form of the skull is long and low, the frill, which is twice as broad as long, being but little elevated behind, in contrast to most of the other species except *flabellatus*.

The median ridge of the parietal region is elevated and bears four rugose prominences, wherein *T. serratus* differs from *flabellatus* and *elatus*, but agrees with *prorsus* and *brevicornus*.

The number of epoccipitals is seventeen, five pairs being borne on the squamosals. In this, as in other features, the type specimen agrees with No. 970 of the American Museum, a much larger though still immature skull which the present writer[a] has referred to the same species.

5. *Triceratops (Bison, Ceratops) alticornis* Marsh (pp. 115–116, fig. 106) is known only from a pair of remarkable supraorbital horn cores (No. 1871E, U. S. National Museum), first referred by Marsh to *Bison* and later to *Ceratops*. Hatcher has removed the species to the present genus for reasons which are at once evident when one contrasts the generic characters of *Ceratops* and *Triceratops*, especially with reference to the relative development of the elements represented by the type.

The supraorbital horn cores are long, with slender-pointed ends, curving forward and outward, then upward.

These horn cores resemble possibly those of *serratus* more than any other species and represent the most highly specialized type within the genus. The frontal region is broad, somewhat convex, and very rugose.

6. *Triceratops sulcatus* Marsh (pp. 133–134, figs. 112, 113, Pl. XXXVII) is based upon some skull and skeletal fragments (No. 4276, U. S. National Museum) of a very large, fully adult animal.

In the original description Marsh describes a deep groove on the posterior surface of the upper half of the supraorbital horn core. Unfortunately but one horn core is now available, and it is incomplete, evidently having been broken off and healed over during the life of the individual. This core does not show the distinctive groove, and Hatcher is inclined to give the presence or absence of the groove but little specific weight.

The horn was ovate in cross section and as preserved shows no distinctive characters. This is also true of the humerus and vertebræ which are preserved.

On the whole there seem to be no characters in the fragmentary material representing the type which afford a basis for a true specific diagnosis. It would be well, therefore, to await the discovery of additional material before deciding as to the validity of this species.

7. *Triceratops elatus* Marsh (pp. 134–138, Pl. XLIII) is based upon a scarcely adult specimen of large size (No. 1201, U. S. National Museum). The rostral bone is of moderate size and is not coossified with the premaxillaries, the upper branch being free.

The nasal horn core is short and stout, its posterior border not being continuous with the upper surface of the nasals as in most species. The apex rises but little above the superior border of the nasals. Another skull (No. 4805, U. S. National Museum) has a horn intermediate between that of the type and that of *T. calicornis*, evidently the nearest ally to the species under discussion.

The supraorbital horn cores are long and massive, curving strongly forward as in *T. calicornis*, much compressed laterally except toward the apex, where they become nearly circular.

The orbit is large, elliptical, with a somewhat oblique axis.

The inferior process of the jugal is directed downward and backward at an angle of 45°, in contrast to other species, wherein it is more nearly vertical.

The frill is much elevated toward its posterior margin and differs from that of other species in the absence of undulations along the margin of the squamosal, this bone being rather sharp edged and regular in outline. Epoccipitals were borne on the parietals and the posterior half of the squamosals only. The number of epoccipitals was fourteen, four pairs on the squamosals and six on the parietals, without the usual median one.

[a] Bull. Am. Mus. Nat. Hist., vol. 19, pp. 685-695, Pl. LIX.

8. *Triceratops calicornis* Marsh (pp. 138–139, Pls. XXXVIII–XL) is based upon a large but immature skull, jaw, dorsal vertebræ, ribs, pelvis, sacrum, etc. (No. 4928, U. S. National Museum).

The specific affinities would seem to be with the preceding species, *T. elatus*, from the similarity of both nasal and supraorbital horns and of the frills. The main distinctions lie in the proportions of the skull of the present species, as the premaxillaries are here much longer and the rostral bone larger, with a much fuller anterior curve, thus making that portion of the skull in advance of the nasal horn proportionately much more pronounced.

The nasal horn core is low, almost vertical, convex in front and concave behind. *T. calicornis* agrees with *T. elatus* in having the small nasal horn core sharply marked off from the nasals, not apparently continuous with them as in most species.

The descending process of the jugal differs from that of *T. elatus* in being more nearly vertical, as in other species. This may, however, as Hatcher says, be due to difference of pressure in the two types.

The frill is only in part preserved, but the squamosals are almost entire. They agree with those of *T. elatus* in lacking marginal undulations and apparently bore but three or four epoccipitals on the posterior portion, which are not ankylosed. The squamosals are longer and narrower, a fact which aids in giving to the entire skull a greater proportionate length than that of *T. elatus*. The lachrymal foramen is between the nasal and maxillary in both species, thus agreeing with *serratus* and *flabellatus*. Hatcher expresses the opinion that *T. elatus* and *T. calicornis* may prove synonymous.

9. *Triceratops* (= *Sterrholophus*) *flabellatus* Marsh (pp. 143–148, figs. 6, 8–11, 15, 17–23, 28, 31, 33, 36, 38, 39, 43, 44, 60–62, Pls. XLIV–XLVI) is known from the nearly complete though disarticulated skull of a very young individual (No. 1821, Yale Museum). This species Marsh made the type of a new genus, *Sterrholophus*, because of the character of the frill, but, as shown above (p. 164), the peculiar absence of vascular impressions from the latter may be considered an adolescent character, which may also be said of each presumably generic feature exhibited by the skull.

The nasals are massive, but not yet coossified, nor was the nasal horn core ankylosed, so that this important feature is lacking.

The supraorbital horn cores are rather long, laterally compressed near the base but more nearly circular in section toward the summit. They are inclined forward and outward at a less angle than in other species.

The orbit is elliptical and the lachrymal foramen lies entirely within the maxillary bone as in *T. prorsus*.

The long axis of the frill exhibits less of an upward curve than in other species except *T. serratus*.

The squamosals are rather short and broad, as in *T. serratus*, though the entire frill viewed from above is proportionately much narrower because it is more highly arched.

T. flabellatus bore upon its frill the maximum number of epoccipitals known, nineteen, of which six pairs are attached to the squamosals, the remaining seven upon the coalesced parietals.

10. *Triceratops obtusus* Marsh (pp. 140–141, figs. 116, 117) is known from portions of a skull (No. 4720, U. S. National Museum) representing a large, adult animal.

The nasals are very broad and the nasal horn core is reduced to a broad, rounded, rugose prominence marked with a number of deep vascular grooves.

The dentary is described as exceptionally deep and massive, and the teeth are unusually large. The extreme forward extension of the mandibular fossa seen here is exceptional among Ceratopsia.

RELATIONSHIP OF SPECIES.

If one were to group the species of *Triceratops* according to affinities the result would be expressed something as follows:

Group 1.	Group 2.
T. horridus.	*T. elatus.*
T. prorsus.	*T. calicornis.*
T. brevicornus.	

T. serratus and *T. flabellatus* would each stand alone, although in some features they suggest each other.

Of the species *alticornis*, *sulcatus*, and *obtusus* the skulls are too fragmentary for a fair comparison. *T. obtusus*, because of its greatly reduced nasal horn, and *alticornis*, from the development of the long, slender supraorbitals, seem to be the most specialized.

II. THE CERATOPS-TOROSAURUS PHYLUM.

CERATOPS.

Of the four species mentioned under this genus in the alphabetical list on pages 11–12, two, *C.* (*Bison*) *alticornis* and *C. horridus*, have been removed to the genus *Triceratops*, with which their affinities clearly lie, and one, *C.* (*Hadrosaurus*) *paucidens* (pp. 103–104), is of questionable validity, for, as Hatcher says:

> It is not at all unlikely that the type of the present species [a maxillary and premaxillary] pertained to one of the several species of Ceratopsidæ already described as from the Judith River beds. Since, however, the teeth, the maxillaries, and the premaxillaries of all these are imperfectly known, it is at present impossible to determine to which of them this specimen should be referred.

Thus there remains of the original four but one, the type species *C. montanus*, to which Hatcher has added three which he removed from the genus *Monoclonius*.

The list of species as revised by Hatcher is as follows:

1. *Ceratops montanus* Marsh. Type.
2. *Ceratops canadensis* Lambe.
3. *Ceratops recurvicornis*[a] Cope.
4. *Ceratops belli* Lambe.

1. *Ceratops montanus* Marsh (pp. 100–102, figs. 103 and 104), the type species, is based upon an occipital condyle and a pair of supraorbital horn cores, No. 2411, National Museum.

The supraorbital horn cores were of moderate length, subtriangular in section at the base, but nearly circular in the upper half. They are not compressed, but curve strongly outward and slightly forward. The frill is unfortunately unknown in the type species.

2. *Ceratops* (*Monoclonius*) *canadensis* Lambe (pp. 93–96, figs. 96, 97, Pls. XVIII, XIX, XXIII) is known from portions of a skull and an anterior dorsal (No. 1254 a, b, c, d, e of the Canadian Geological Survey). Hatcher removed this species from the genus *Monoclonius* because of the similarity of the supraorbital horn core with that of the type species of the present genus. He does not, however, give us his final decision as to whether it is to be considered specifically distinct from *C. montanus* or not, as that point was left for the present discussion, which Hatcher unfortunately did not live to undertake.

The only distinction must lie in the character of the supraorbital horn cores, which, although Hatcher considers them "essentially the same," seem to differ in that the base is subtriangular in section in *C. montanus* and circular in *C. canadensis*. Another distinction lies in the curvature of the horn. In *canadensis* the horns curve well forward, then upward, but in *montanus* they are more nearly straight and, if Hatcher's arrangement expressed in fig. 103 is correct, flare outward strongly in a most peculiar manner.

The nasal horn core was lost before fossilization, as the creature was young, so that its characters can not be determined.

[a] The present writer questions the reference of *recurvicornis* to this series for the reasons given on page 173.

The squamosal is somewhat triangular, flat, and moderately thin, the outer edge rounded and wavy in outline. One can not contrast it with those of the other species, for with them the element is unknown. (Pl. XXIII.)

All that is preserved of the parietals is a slender bar, triangular in section, which formed the external boundary of the parietal fontanelle. This outer bar is very similar to that of *Torosaurus gladius*.

Hatcher says with reference to this species:

> I have little hesitancy in asserting that the squamosal and frontal horn cores of the present species were associated with a parietal of the same general type as that described by Lambe and referred to *Monoclonius belli*, and I am of the opinion that the two may be specifically identical, although from the material at hand it is impossible to determine this point with certainty.

3. *Ceratops* (*Monoclonius*) *belli* Lambe (pp. 96–97, fig. 98, Pl. XXI) is founded upon a pair of parietal bones (No. 491, Canadian Geol. Survey).

The species was described as *Monoclonius* by Lambe, but was removed to the present genus by Hatcher, for, as he says:

> After a careful study of the type of the present species, together with that of *M. canadensis* Lambe, one can not avoid being convinced as to their generic identity with *Ceratops montanus* Marsh, while at the same time the great dissimilarity shown in the parietals and squamosals of these species when compared with the same elements in *Monoclonius dawsoni* Lambe affords evidence additional to that already pointed out as obtaining in the frontal horn cores, in favor of the generic distinction of the three former species from that of the last-mentioned species.

The character of these parietals has already been sufficiently discussed, especially since a specific comparison can not be made, as the elements are unknown elsewhere in the genus except for the outer parietal bar of the type of *canadensis*.

The material now available affords scant ground for specific distinctions between *C. montanus*, *C. canadensis*, and *C. belli*, and future discoveries may show that these are synonymous.

INCERTÆ SEDIS.

4. *Ceratops* (*Monoclonius*) *recurvicornis* Cope (pp. 81–87, fig. 90) is based upon fragments of the skull of a young individual (No. 3999, American Museum of Natural History).

Nasal horn core massive, curving strongly forward, heavier than the supraorbitals and much more compressed distally. The nasal bones narrow rapidly anteriorly, so as to appear wedge shaped when viewed from above.

The supraorbital horn cores are short, stout, abruptly pointed, and compressed at the subtriangular apex. The horns are straight, almost erect, in sharp contrast with those of other *Ceratops* species, and are relatively much smaller, though they show a decided advance over those of *Monoclonius*. There seems to have been a lesser horn core just in front of the supraorbital horn, subtriangular in cross section and directed forward. This feature is unknown elsewhere.

The squamosal is stout and of considerable size, with no vascular grooves, evidently a juvenile character, and the edge bears prominences which in turn bear epoccipitals separated by sutures from the squamosal bone.

This species has been removed by Hatcher from the genus *Monoclonius* mainly because of the supraorbital horn cores, which resemble those of *Ceratops montanus* much more than those of *Monoclonius crassus*. The squamosal is so different from that of the type species *M. crassus* that, when taken into consideration with the structural differences found in other portions of the skull, especially the horn cores, Hatcher does not hesitate to refer it to the genus *Ceratops*.

The presence of separately ossified epoccipital bones in this species, which do not seem to occur elsewhere either in the genus or phylum, together with the size, which is decidedly greater than that of most of its contemporaries, added to the differences between the supraorbital horn cores and those of other members of the genus *Ceratops*, leads the present writer to doubt the correctness of Hatcher's conclusions in the matter. It should doubtless be removed from *Monoclonius*, but it seems rather to represent a new genus in the *Triceratops* phylum. In the light of our present knowledge, however, this matter can not be settled.

TOROSAURUS.

1. *Torosaurus latus* Marsh (pp. 150-152, fig. 118) is based upon a specimen (No. 1830, Yale Museum) consisting of an incomplete skull of an aged individual.

Nasal horn core broad at base, sharp above, directed upward and forward. Supraorbital horn cores much compressed, ovate, with apex forward. Horn cores directed upward and outward and forward.

Supratemporal fossæ relatively larger than in *T. gladius*.

Skull broad and massive between the orbits. Parietal fontanelles not entirely within the parietals, in contrast to those of *T. gladius*. Hatcher says that he can not verify this feature in *latus*.

The postfrontal fontanelle paired, as opposed to single median one in *T. gladius*.

2. *Torosaurus gladius* Marsh (pp. 152-155, figs. 7, 12, 14, and 119) is based upon a type specimen (No. 1831, Yale Museum) consisting of detached portions of a skull.

Nasal horn core very short, stout, compressed, with a sharp apex. It is very rugose, the section being an oval with the rounded portion in front.

The supraorbital horn cores are rather long, slender, somewhat compressed laterally, and very rugose. They were directed forward and outward.

The postfrontal fontanelle seems to have been single, as opposed to the paired ones in *T. latus*, but the broken condition of the skull in this region leaves this point somewhat in doubt.

The supratemporal fossæ are proportionately smaller than in *T. latus*, and the fontanelles are entirely surrounded by the parietal bones.

Hatcher says: "The type of the present species represents the extreme development of the form of parietal crest that is peculiar to this genus," though *T. gladius* is geologically the older of the two species.

GEOLOGY AND PHYSIOGRAPHY OF THE VARIOUS CERATOPSIA LOCALITIES.[a]

The remains of Ceratopsia, though referred by various authors to each of several horizons, are referable either to the Judith River of Montana and its equivalent, the Belly River of Canada, or to the Laramie of Wyoming and Montana and the Denver and Arapahoe formations of Colorado.

The principal geographical localities, as well as one or two minor places from which Ceratopsia remains have been reported, are shown on the accompanying map (Pl. L).

The vertical range of the Ceratopsia is limited to the upper half of the upper Cretaceous.

JUDITH RIVER LOCALITIES OF MONTANA.

CORRELATION.

The conclusions reached by Messrs. T. W. Stanton and J. B. Hatcher[b] concerning the stratigraphic position of the Judith River beds and their correlation with the Belly River formation are of prime importance in considering the phylogeny of the Ceratopsia. These general conclusions, based upon a careful resurvey of the upper Cretaceous formations in Montana and the adjacent parts of Canada having special bearing upon the problems in hand, are as follows:

> 1. The Judith River beds are distinctly older than the Laramie, being separated from the latter by at least several hundred feet of marine shales, identical in their faunal and lithologic features with the Pierre, to which we have given the local name of Bearpaw shales, from the Bearpaw Mountains, about which they are well exposed.
>
> 2. The Belly River beds of Canada are identical with the Judith River beds of Montana. The name Judith River beds having priority should be the accepted name for this formation, and the terms Belly River and Fish Creek beds should be dropped.
>
> 3. The marine sandstones and shales immediately underlying the Judith River beds do not represent either the Benton, as some Canadian geologists have supposed, or the Fox Hills and upper Pierre, as most geologists of the United States who

[a] Based upon the writings of Hatcher, Stanton, Lambe, Eldridge, Cross, and upon the writer's own explorations.

[b] Geology and paleontology of the Judith River beds: Bull. U. S. Geol. Survey No. 257, p. 66, 1905.

have examined them have believed, but they constitute a distinct horizon within the Montana group, which we have called the Claggett formation, from old Fort Claggett, at the mouth of the Judith River, near which they are well developed.

4. The Eagle formation, from its stratigraphic position and faunal relations, marks the base of the Montana group in this region.

5. The Bearpaw shales, the Judith River beds, the Claggett, and the Eagle formations all belong to the Montana group, and together probably form the equivalent of the Pierre, as that term is generally understood, though the possibility is recognized that in the typical area the Pierre may have more restricted limits.

The following correlations are shown:[a]

Sections in South Dakota, Montana, and Assiniboia.

	South Dakota section.	Central and northern Montana section.	Southern Assiniboia section.
	Laramie.	Laramie?	Laramie?
Montana group.	Fox Hills.	Fox Hills?	Fox Hills?
	Pierre.	Bearpaw. Judith River. Claggett. Eagle.	Bearpaw. Belly River (Judith River). Claggett. (?)
Colorado group.	Niobrara. Benton.	Benton.	(?)
	Dakota.	Dakota?	(?)

The Montana and Colorado groups are generally recognized as larger subdivisions of the strata lying between the Dakota and the Laramie. The South Dakota and Nebraska section is the Meek and Hayden section with the Laramie added, while the other two columns represent the sections studied by us [Stanton and Hatcher]. The queries in the lower part of the columns indicate formations not seen by us, and the queries in the upper part of the columns indicate our doubts as to the correlation of any particular horizon in these sections with the Fox Hills and as to the limits of the Laramie and its relationship with overlying formations that have been described in this region.

DOG CREEK.

The first Judith River locality mentioned by Stanton and Hatcher is at Dog Creek, a small stream emptying into the Missouri from the south, about 2 miles below the mouth of Judith River. This creek rises in the Moccasin Mountains and flows for 25 or 30 miles northward, first in a narrow and shallow valley, through grass-covered table-lands, and for the last 12 or 15 miles through a deep, rugged canyon, with wild, deeply dissected badlands on either side.

The walls of the upper valley are composed of Judith River sandstones and shales; those of the deeper lower canyon are mainly the light ash-colored sandstones and darker shales and clays of the Judith River beds above and "the darker buff-colored sandstones and dark sandy or black clay shales of the underlying Claggett formation" below.

For 5 to 8 miles from the mouth of Dog Creek the beds in the bluffs of the stream are undisturbed, and in this stretch the Claggett underlies 300 or 400 feet of Judith River formation.

A little farther up Dog Creek, in undisturbed areas, the Claggett formation disappears beneath the bed of the stream, and the bluffs of the canyon are formed entirely of the Judith River beds, which have a maximum thickness here of perhaps 500 feet and are composed below of alternating layers of light, ash-colored sandstones and darker shales, abounding in numerous fresh-water Mollusca.[b]

[a] Loc. cit., p. 63.

[b] Stanton and Hatcher, op. cit., pp. 37-38.

Among the ceratopsian remains mentioned are those of *Ceratops* and *Monoclonius*, and it was here, or in this vicinity, that type material referred to *Ceratops paucidens* Marsh was found, the exact locality being—

on the western slope, very near the summit, of a rounded badland hill about 20 rods east of the spring situated about one-quarter of a mile east of the freight road running from Judith to Maiden, Mont., * * * about 12 miles from Judith post-office, on the Missouri River. [See this monograph, p. 103.]

The type of *Ceratops* (*Monoclonius*) *recurvicornis* Cope was found in a bluff on the north side of Missouri River nearly opposite the mouth of Dog Creek, in Montana. According to Cope the geological horizon was near the base of the Judith River beds as these are represented in this locality.

BIRCH CREEK.

Birch Creek rises in the Bearpaw Mountains and flows southward, emptying into the Missouri River nearly opposite the mouth of Dog Creek. The walls of the canyon of Birch Creek are composed of Judith River and underlying formations, while the hills on either side of the

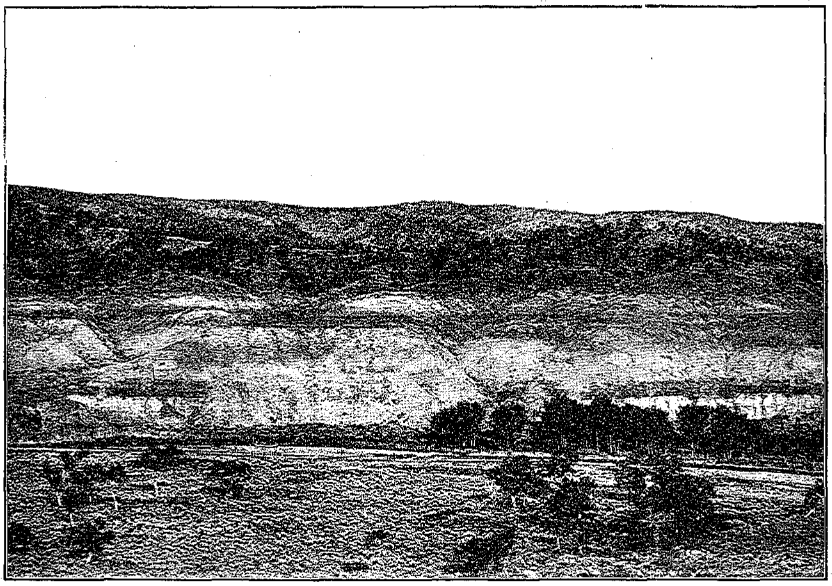

FIG. 121.—Undisturbed Judith River beds, with overlying Bearpaw shales, on Cow Creek, Montana. After Stanton and Hatcher. The contact is below the pine trees on ridge in middle distance.

canyon are formed of the Bearpaw shales. It was from the sandstones near the base of the Judith River beds near the mouth of Birch Creek that Professor Cope, in 1876, secured the type of *Monoclonius crassus*.

The type of *Monoclonius sphenocerus* Cope was found by Charles H. Sternberg on the Missouri River near Cow Island, Montana; level not recorded.

COW CREEK.

Cow Creek, which yielded the type of *Ceratops montanus* Marsh, flows south from the Bearpaw Mountains, emptying into the Missouri about 30 miles below Judith post-office.

Cow Creek flows in a deep, rugged canyon from a place a short distance below the point where it leaves the Bearpaw Mountains to its confluence with the Missouri. * * * The bluffs on both sides of Cow Creek for several miles above its mouth are made up largely of rocks belonging to the Claggett formation, overlain by the lighter colored materials of the Judith River beds.

These exposures are similar to those of the same formations on Dog and Birch creeks, and frequent faulting exposes here and there the underlying Eagle sandstones and Benton shales.

About 10 miles above the mouth of Cow Creek, at the point where the old Fort Benton and Cow Island freight road leaves the creek and turns westward toward the Bearpaw Mountains, there is a conspicuous fault in the Judith River beds. Immediately south of the fault * * * a prominent ridge composed of sediments belonging to the Judith River beds projects into the valley of the creek. The type of *Ceratops montanus* [pp. 100-102] was obtained near the summit of this ridge.

Accompanying *Ceratops montanus* were *Trachodon mirabilis*, crocodiles, fishes, turtles, and a number of fresh-water invertebrates.

JUDITH RIVER (BELLY RIVER) LOCALITIES IN CANADA.

It is to the explorations and consequent publications by Mr. L. M. Lambe, vertebrate paleontologist to the Geological Survey of Canada, that we are indebted for a considerable enriching of our knowledge concerning the earlier Ceratopsia.

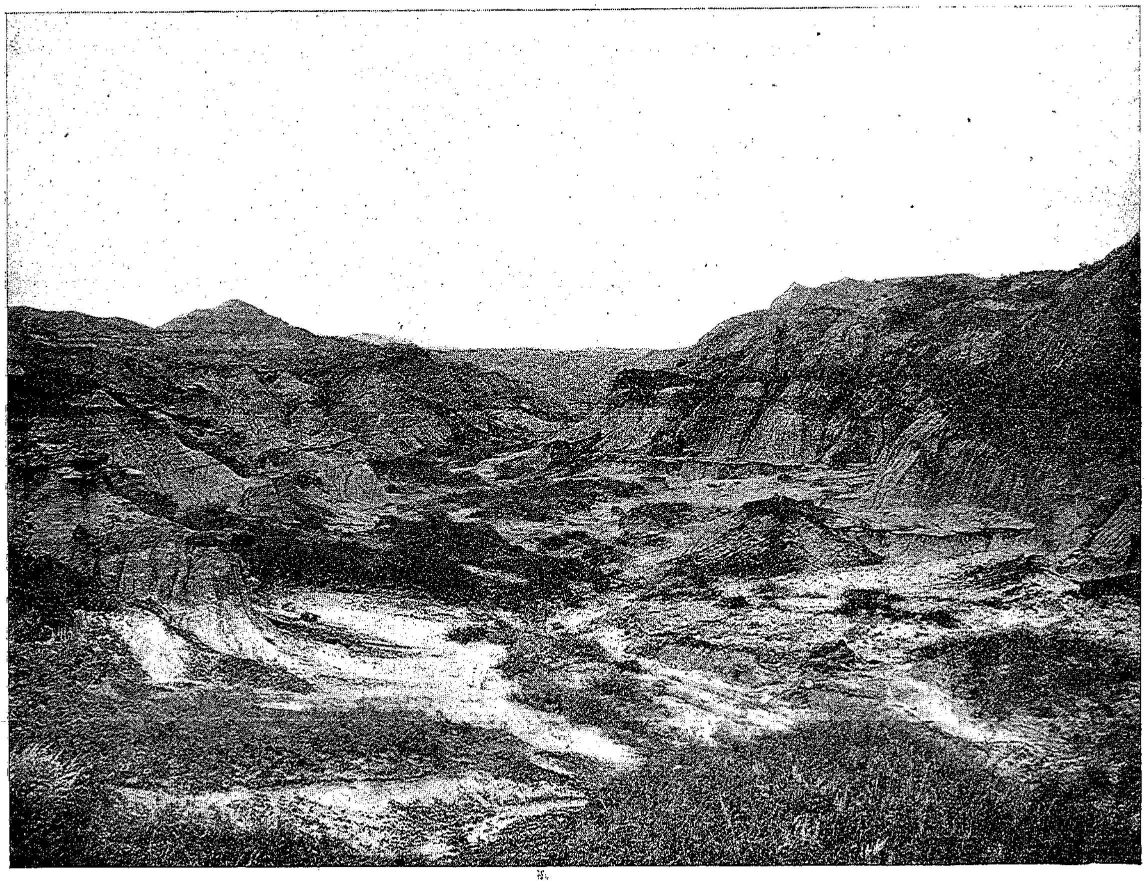

FIG. 122.—View of the west side of the valley of Red Deer River, Alberta, showing the lower Belly River beds. After Lambe.

Stanton and Hatcher, in speaking of the Belly River exposures, say:

The exposures examined by us in Canada are all in the southeastern portion of the large, continuous area of Belly River beds mapped by Dawson, McConnell, and Tyrrell. They include both the top and bottom of the formation, as well as good exposures of the overlying and underlying beds, and hence give a fair idea of the formation as described by Dawson. The principal localities that have yielded the Belly River vertebrate fossils described by Lambe are on Red Deer River some distance north of the most northern point visited by us, but we have no doubt that they are on the same horizons which we studied.

The genera and species of Ceratopsia described by Lambe were collected from the Judith River (Belly River) beds in the Red Deer River district of Alberta, in the summers of 1897, 1898, and 1901. Mr. Lambe says of these explorations:[a]

In 1897 the writer descended the Red Deer River, starting from the village of Red Deer (in Alberta), and made collections from the Edmonton subdivision of the Laramie, between Red Deer village and Willow Creek, and from the Belly River series between Bull Pound Creek and Dead Lodge Canyon.

[a] Contr. Canadian Pal., vol. 3 (quarto), pt. 2, p. 25.

He says, further:

In this year, however, it was found that the best results were obtained in the Belly River series in the vicinity of Berry Creek. Accordingly this locality was revisited in 1898 and again in 1901 and collections made from the Belly River series only, in an extensive area of "badlands" on either side of Red Deer River between Berry Creek and Dead Lodge Canyon.

This locality is in Alberta, just west of the border between that Province and Assiniboia. In speaking of the Belly River series Dr. G. M. Dawson[a] says:

In the region of the Bow and Belly rivers the Pierre is underlaid by an extensive fresh and brackish water series, consisting of sandy argillites and sandstones; the upper portion is characteristically pale in tint, the lower generally darker and yellowish or brownish. This has been called the Belly River series and appears to correspond precisely to that occupying a similar stratigraphical position on the Peace River and there designated the Dunvegan series. These indicate the existence of a prolonged interval in the western Cretaceous area, in which the sea was more or less excluded from the region and its place occupied for long periods by lagoons or fresh-water lakes.

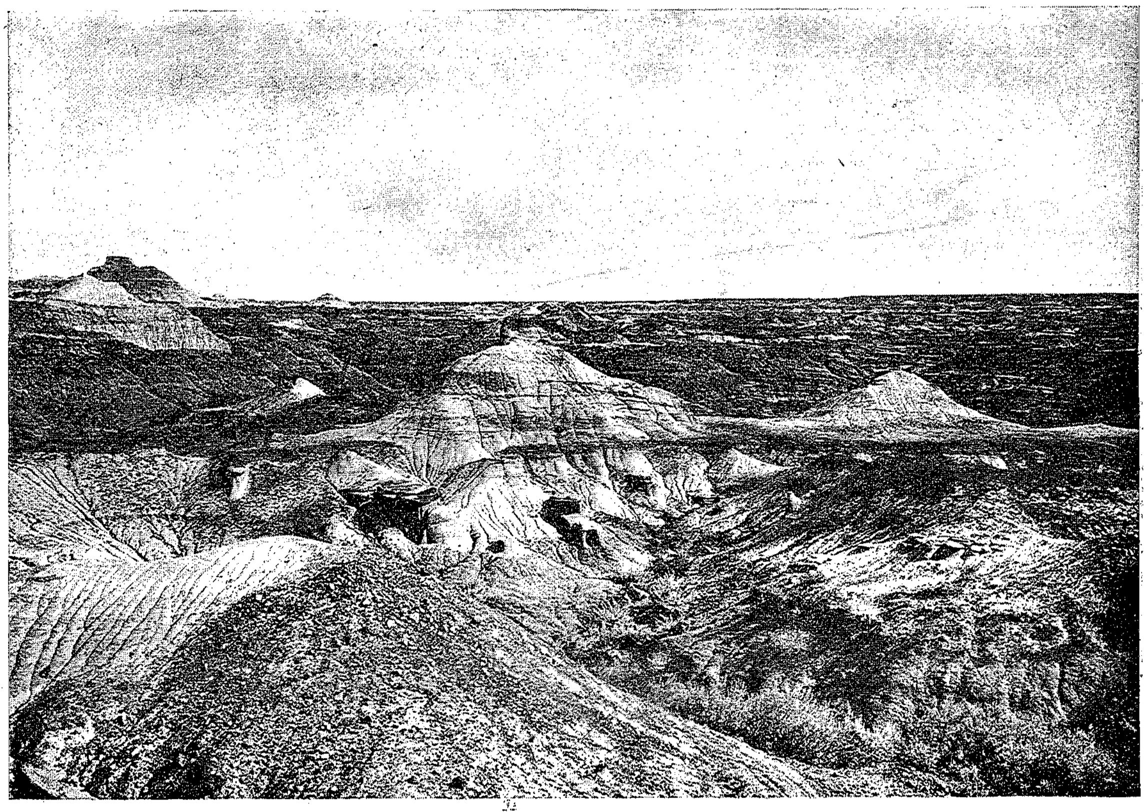

FIG. 123.—View in the valley of Red Deer River, Alberta, upper (primitive mammal) Belly River beds, on east side of the stream south of Berry Creek. After Lambe.

Mr. Lambe, in a letter to the writer dated May 30, 1905, writes:

All my specimens are from near the mouth of Berry Creek, on the Red Deer River, and the rocks there exposed, I was of the opinion, belonged to the upper or "pale" portion (of Doctor Dawson). * * * On either side of the Red Deer River below the mouth of Berry Creek there is an area of "badlands" about 6 to 8 miles, roughly, in diameter. * * * I camped on the river bank on both sides and obtained all the types in this area.

In this upper half of the series there is a great similarity in the beds all through, but for convenience of reference in my field notes I refer to further subdivisions which I have named *lower, middle,* and *upper* (primitive mammal) beds. The upper photograph in my memoir,[b] facing page 25 [fig. 122], shows a characteristic view of the lower beds. The other, the lower photograph [fig. 123], is taken from the level of the upper or primitive mammal beds which at this locality [Red Deer River, at and below mouth of Berry Creek] apparently reach the prairie level, which is seen in the photograph as the distant horizontal line. It is from this upper level that I obtained the type of *Ptilodus primævus.*

[a] Descriptive sketch of the physical geography and geology of the Dominion of Canada, by A. R. C. Selwyn and G. M. Dawson, Montreal, 1884, p. 40.

[b] Contr. Canadian Pal., vol. 3 (quarto), pt. 2.

The specimens representing the species of Ceratopsia may be placed with regard to their horizons as follows:

Cat. No. 971, *Centrosaurus apertus*	Lower beds.
Cat. No. 1254, *Monoclonius canadensis*	Lower beds.
Cat. No. 1173, *Monoclonius dawsoni*	Middle beds.
(These beds should possibly be included with the upper beds.)	
Cat. No. 491, *Monoclonius belli*	Upper beds.
Cat. Nos. 515, 1423, etc., *Stegoceras validus*	Upper beds.

The types, as regards their geographical position, are as follows:

971 (*Centrosaurus apertus*). West side of Red Deer River, July 26, 1901. Not far from it were remains of *Trionyx foveatus,* Leidy.

1254a, etc. (*Monoclonius canadensis*). East side of Red Deer River, August 2, 3, and 20, 1901. At same level and near remains of *Trachodon.*

1173 (*Monoclonius dawsoni*). East side Red Deer River, August 15, 1901.

491 (*Monoclonius belli*). East side Red Deer River, below the mouth of Berry Creek, August 13, 1898. Not far distant and at the same level were found remains of *Trachodon, Cimoliasaurus,* and turtles.

515 (*Stegoceras validus*). East side Red Deer River, below the mouth of Berry Creek, August 15, 1898; 1423, east side, August 24, 1901. At about the same level as *M. belli, Ornithomimus altus, Adocus variolosus, Baëna antiqua, Trionyx foveatus,* etc., *Ptilodus primævus, Myledaphus bipartites, Lepidotus occidentalis, Diphyodus longirostris,* etc.

There seem to be no very distinct lithological differences on which to base these subdivisions of the Red Deer River rocks, but the lowermost beds seen in the area below the mouth of Berry Creek include some yellowish sandstones, which may be the uppermost beds of Doctor Dawson's lower yellow portion.

LOCALITIES FOR LARAMIE CERATOPSIA.

The main localities for Laramie Ceratopsia are three in number—one near Black Buttes station on the Union Pacific Railroad, in southwestern Wyoming; a second, by far the most notable, in the northeastern part of Converse County, Wyo., in the area shown on the map (Pl. LI), and a third in the canyon of Hell Creek, Montana, a tributary of the Missouri, about 135 miles northwest of Miles City.

THE BLACK BUTTES, WYOMING, LOCALITY.

The Black Buttes locality is interesting historically as having produced one of the first specimens of ceratopsians, the type specimen of *Agathaumas sylvestris* Cope. It lies in Sweetwater County, in southwestern Wyoming, not far from Black Buttes station on the Union Pacific Railroad.

Stanton and Knowlton[a] describe this locality as follows:

> The most prominent feature of the section at Black Buttes is the massive bed of sandstone, somewhat over 100 feet thick at the base of the exposure, forming steep hills and cliffs northeast of the railroad opposite the station and passing beneath the surface by its dip of 9° or 10° near the coal mine. * * * The original specimen of *Agathaumas sylvestris* was found about 20 feet above it.

The bones were found, according to Cope, in a bed of sandstone that lies just above the lower stratum of the Bitter Creek series of coals and is overlain by two other coal seams. This bed of sandstone "crops out high on the bluffs" a half mile east of the station.

From the molluscan fauna it is judged that the beds below and above the dinosaur bed consisted mainly of deposits from brackish water, with alternations of fresh-water deposits and of coal seams, probably implying coastal swamps with abundant vegetation in which frequent slight changes of level occurred, bringing in brackish waters during periods of subsidence and fresh waters during periods of elevation. This would produce physical conditions in keeping with our conception of the environment of the Ceratopsia. (See p. 194.)

THE CONVERSE COUNTY, WYO., LOCALITY.

The history of the discovery by Mr. Hatcher of this, the most important Ceratopsia locality, has already been stated (pp. 7–9), and a description of the location and character of the deposits is given in an earlier paper by Hatcher (Am. Jour. Sci., 3d ser., vol. 45, Feb., 1893, pp. 135–144), from which I shall quote at length. The beds were reached by Hatcher by going north from the town of Lusk, Wyo., on the Fremont, Elkhorn and Missouri Valley Railroad; now they

[a] Bull. Geol. Soc. America, vol. 8, p. 143. (See also pp. 105–106.)

are more readily accessible from Edgemont, S. Dak., on the Burlington and Missouri division of the Chicago, Burlington and Quincy. The Ceratops beds first appear about 25 miles north of Lusk—

occupying the summit and northern slope of a yellow sandstone ridge extending in a westerly direction from Buck Creek to Lance Creek and crossing the latter stream near the mouth of Little Lightning Creek, a small tributary from the west. A short distance west of Lance Creek the Ceratops beds pass under other beds composed of very similar material and presumably of Cretaceous age. From Buck Creek the eastern border of the Ceratops beds has been traced in an almost continuous exposure extending northeastward to the Cheyenne River and crossing this stream a short distance below the mouth of Lance Creek. From this point it takes a more northerly direction and, skirting the western slope of the Black Hills, it has been traced to the north line of Converse County and on into Weston County. * * * The Ceratops beds were originally confined to the western slope of the Black Hills and of the less elevated series connecting the latter with the Rawhide Range. * * * In no instance have the Ceratops beds been observed east of the Black Hills or their less elevated continuation to the southwest.

The Ceratops beds proper—that is, those beds containing remains of the Ceratopsidæ—are known to have a surface exposure in that portion of Converse County embraced within their eastern and southern border, as defined above, and a line extending from that point on the latter where it passes under the overlying beds a short distance west of Lance Creek, nearly due north to Weston County, i. e., the country drained by lower Lance, Lightning, Cow, Doegie, and Buck creeks, and that portion of the Cheyenne River and its tributaries between the mouth of Lance Creek and the north line of Converse County.

Most of these creeks are shown on Pl. LI, which was originally drawn by Hatcher to accompany the paper just cited, but was not published until later.[a]

The Ceratops beds are made up of alternating sandstones, shales, and lignites, with occasional local deposits of limestones and marls. The different strata of the series are not always continuous, a stratum of sandstone giving place to one of shales and vice versa. This is especially true of the upper two-thirds of the beds. The lack of continuity has rendered it well nigh impossible to establish any definite horizons in the upper members of the series. All the deposits of the Ceratops beds of this region bear evidence of having been laid down in fresh waters. Among the invertebrate fossils found in them, only fresh-water forms are known. * * *

The sandstones largely predominate in the lower members of the beds. They are always fine grained, massive to well stratified, and nearly white to yellowish brown in color. They are occasionally compact and hard, but for the most part quite soft and friable. * * * Almost everywhere in the sandstones are numerous concretions of varying size and shape. Some are almost perfect spheres and vary from the size of a marble to 18 to 20 feet in diameter. Others are from a few inches to several feet in transverse diameter and sometimes several hundred feet in length, a cross section forming a nearly perfect circle. Others still are very irregular in form. These concretions usually show no concentric structure, and while they sometimes inclose foreign objects, as a *Triceratops* skull or a single bone as a nucleus, they are for the most part simply centers of solidification and not true concretions. This is frequently shown by the cross bedding in them, so often seen in the sandstones themselves. * * *

The lignites occur in thin seams, never more than a few inches thick, of only limited extent, and with many impurities. At no place in the Ceratops beds of this region have workable coal beds been found.

The exact localities of the type specimens from the Converse County beds are as follows:

Triceratops horridus at the point marked +1, Pl. LI, on the south side of a canyon entering Buck Creek from the west and about 5 feet from the bottom of the canyon, contained in a concretion formerly embedded in a light-yellow, soft, heavily bedded sandstone.

Stratigraphically *T. horridus* came "from midway between the Fox Hills and Fort Union" of Converse County. Hatcher estimates the stratigraphical range from the locality of the type of *Ceratops montanus* to that of the present species as 3,500 feet, allowing 2,000 feet for the Bearpaw shales and true Fox Hills sandstones and 1,500 for the Laramie below the skull level. (See p. 119.)

The type of *Triceratops* (*Sterrholophus*) *flabellatus* was found at the point marked +2 in Pl. LI, where "it lay in a bed of arenaceous shale, at the summit and the extreme western point of a high and rocky ridge about half a mile in length, running westward from the main divide between Buck Creek and Lance Creek."

Stratigraphically it lay above the position of any other type, with the possible exceptions of *T. sulcatus* and *T. brevicornus*.

Triceratops prorsus, type, lay at the locality marked +3 in Pl. LI. It was situated on Dry Creek, which empties into Lance Creek from the west, about 3 miles above the mouth. It lay on the north side, about 100 yards above the location of the type of *T. serratus*, in a hard

[a] Am. Naturalist, Feb., 1896, vol. 33, Pl. III.

concretion of calcareous sandstone which had weathered out of a thick stratum of soft and almost white sandstone. It was at a slightly lower level than *T. serratus*. The skeleton [a] referred to *T. prorsus* probably comes from nearly the same horizon as the type.

The type of *Triceratops serratus* lay about 20 feet above the bottom of the same side of the draw at the point marked +4, Pl. LI. This skull was in the usual calcareous concretion at the base of a stratum of sandstone. The horizon was slightly above that of *T. prorsus* and considerably above the type of *T. horridus*.

Triceratops sulcatus, type, was discovered at the point marked +5, on the divide between Dry Creek and Lance Creek. Its horizon was a little above that of *T. serratus*, but below the level of *T. flabellatus*.

The locality of the type of *Triceratops obtusus* is at +9, Pl. LI, about 1 mile east of Lance Creek, near the southern border of the Ceratops beds. The horizon "would be about the middle of the Laramie, as those deposits are represented in this region." This would seem to bring the species below the level of *Triceratops horridus*, which is about the middle of the upper half, and hence make it the lowermost species thus far recorded.

Triceratops elatus, type, was found at the point marked +16 on the map (Pl. LI). It lay in loose arenaceous shale a quarter of a mile east of Lance Creek and opposite the mouth of Lightning Creek. The horizon given is about the middle of the Laramie series, which would bring *T. elatus* and *T. obtusus* at about the same level, though, as Hatcher says, owing to the absence of exposures of overlying or underlying deposits in this immediate vicinity it is difficult to determine exact horizons with even moderate precision, and this difficulty is augmented by the frequency with which the sandstones and shales of these deposits replace one another both vertically and laterally, making it extremely difficult to trace any given stratum for any considerable distance. Stanton says the position of *T. elatus* "would not be more than 300 to 400 feet below the highest Ceratopsia remains of this area."

Triceratops brevicornus, type, was discovered embedded in a hard sandstone concretion in the divide between Lance and Lightning creeks, 3 miles above the mouth and 1½ miles south of Lightning Creek, indicated by +22, in Pl. LI. Stratigraphically it lay near the summit of the Laramie deposits, hence is possibly the highest of the known species. Stanton thinks that "its position can not be very much higher than *T. prorsus*, *serratus*, and *sulcatus*."

Triceratops calicornis, the remaining Converse County species, was found at +29, Pl. LI, about a mile east of the abandoned U–L ranch, which is at the junction of Dry and Lance Creeks. It was embedded in a stratum of rather hard sandstone. Hatcher gives us no clue as to the horizon of this specimen. Stanton says, "It is apparently from about the same horizon as *T. sulcatus*."

Of the genus *Diceratops*, with its single species *hatcheri*, the type specimen was found in a hard sandstone concretion about 3 miles southeast of the mouth of Lightning Creek, at the point marked +25, Pl. LI. No statement as to the stratigraphical position is given. From its locality it can not be far from the level of *T. flabellatus*.

Of the two species of the genus *Torosaurus*, one (*T. latus*) was found in an extremely hard bluish-colored calcareous concretion near the top of the bluff on the north side and about 2 miles above the mouth of Lightning Creek. It lay in the bottom and near the extreme head of a small, dry watercourse at the point marked +19, Pl. LI. From its geographical position Stanton believes *T. latus* to be the highest Ceratopsia specimen from this region.

The type of *Torosaurus gladius* came from a horizon considerably lower (200 feet) than that of the preceding species and lay in a thick bed of shale on the northern slope of the divide between Cow and Lightning creeks at + 19A, Pl. LI. Hatcher does not give the stratigraphical position of the two *Torosaurus* species with relation to those of the genus *Triceratops*.

[a] The mounted skeleton, No. 4842, U. S. National Museum.

THE HELL CREEK, MONTANA, LOCALITY.

This locality[a] lies in the northern part of Dawson County, Mont., along the canyon of Hell Creek, a tributary flowing northward into the Missouri River about 30 miles above the mouth of the Milk River and 150 miles east of the Judith River localities. The country has an altitude up to 3,000 feet above sea level and consists of grassy table-lands with occasional flat-topped buttes and, in places along the stream courses, wild dissected badlands.

There seems to be no continuous bone-bearing layer, but occasional localities where specimens, mainly fragmentary, may be found, some in joint clay, some in unconsolidated sandstone, and again in concretions so typical of the Laramie formation.

The American Museum party of 1902 found the remains of thirteen or more skulls, presumably of *Triceratops*, but all had weathered out and disintegrated but one, which was intact except for the nasal horn core, the nasals, and the distal portions of the supraorbital horn cores, which had weathered away. This specimen (see p. 185, fig. 26) was found on the extreme point of the divide separating Hell Creek from a tributary which entered it from the west about 15 miles from the Missouri River. It was about 35 feet from the bed of the canyon and lay in its natural position. The precise horizon was not ascertained.

Few of the Ceratopsia found in this region were in concretions, although the party unearthed portions of the skeleton of an enormous theropod dinosaur (*Tyranosaurus rex* Osborn), which was contained in several bluish calcareous concretions of extremely hard, homogeneous texture. The skull, No. 970 of the American Museum, is doubtless referable to *Triceratops serratus* Marsh.

In addition, the party secured portions of the skeleton of another specimen at a point about a mile south of the place where the first was found and an equal distance away from Hell Creek Canyon. This was also *Triceratops*, but the species has not been determined. It was embedded in joint clay, at the base of a large table butte, the upper portion of which had been baked to a terra cotta from the accidental burning out of the lignite seams.

Two splendid skulls, one probably referable to *Triceratops brevicornus*, were found near Hell Creek, in 1904, by Mr. W. H. Utterback, of the Carnegie Museum in Pittsburg. The *T. brevicornus* skull lay in soft sand and was in perfect condition.[b]

DENVER LOCALITIES.[c]

Ceratopsia remains have been found in the vicinity of Denver, Colo., in beds known as the Arapahoe and Denver, considered to be of post-Laramie age.

The Arapahoe, the older of the two formations, occupies the site of an ancient lake of considerable extent.

> Along the northern and northwestern edges the formation now appears only as a thin horizontal sheet, or in scattered outliers upon the uneven surface of the underlying Laramie. Along the western outcrop, where the strata are highly inclined and confined between underlying and overlying terranes, the formation is 600 to 800 feet thick. * * * The total thickness of the Arapahoe as originally laid down is undeterminable.
>
> The Arapahoe is divisible into two well-marked series of beds; a lower, of sandstones and conglomerates, 50 to 200 feet thick, and an upper, of clay, 400 to 600 feet thick.[d]

The lower member is composed of débris derived from the underlying Carboniferous, the Triassic, the Jurassic, and from the lower divisions of the Cretaceous, up to and including the Laramie. The shales of the overlying member of the Arapahoe are light gray and arenaceous and contain a few ironstones similar to those of the Laramie.

The vertebrate remains "occur in the conglomerate along the foothills and in the basal sandstones and overlying clays beneath the prairies." The few specimens from the conglomerate are worn, while the abundant remains in the clays are finely preserved.

> The Arapahoe formation is distinguished from the Laramie by the sandy nature of its clays, by the comparative paucity of its ironstones, by the generally brighter colors, and by the vertebrate remains. From the overlying Denver the Arapahoe is readily distinguished by the eruptive nature of the material composing the former.[e]

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[a] Lull, R. S., Bull. Am. Mus. Nat. Hist., vol. 19, Art. XXX, Dec., 1903. See also this monograph, p. 185.
[b] Ann. Rept. Carnegie Museum for 1905, p. 24, figure facing p. 64.
[c] Emmons, Cross, and Eldridge, Geology of the Denver Basin: Mon. U. S. Geol. Survey, vol. 27, pp. 150-254.
[d] Eldridge, op. cit., pp. 151-152.
[e] Eldridge, op. cit., p. 154.

Within the area of the Denver Basin the Arapahoe formation rests unconformably upon the Laramie, although along its upturned western edge the break is recognized only through change in sedimentation.

The Denver formation, which lies unconformably upon the Arapahoe, is very different from the latter in the composition of its rocks, though textually they are similar. The materials of which the Denver beds are composed may be classed as the débris of Archean, of sedimentary, and of eruptive rocks. The Archean débris, which is confined to the upper portion of the series, consists of bowlders, pebbles, and sands, and is similar to that of the underlying Arapahoe. The material undoubtedly came from the Archean lands lying to the west.

The sedimentary débris, which is mingled with the Archean in the upper portions of the formation, consists of small sandstone and limestone pebbles derived from the upturned edges of the Mesozoic strata. There are also conglomerate bowlders from the Dakota Cretaceous, while on the plains there is some quartz and feldspar, originally from the Archean but derived immediately from the soft Arapahoe beds.

The eruptive débris is the most characteristic feature of the Denver formation, especially in the lower half, though it ranges to the summit of the beds. These eruptive materials are almost entirely andesitic and imply a period of violent eruptions before the beginning of Denver time.

The total thickness of the Denver is estimated at 1,449 feet.

Fragmentary remains, which doubtless represent several species of Ceratopsia, have been found in the vicinity of Denver; from the Arapahoe is one identified as *Ceratops montanus*, that is "the remains of the same reptile or one nearly allied to it." This identification seems hardly possible, as *Ceratops montanus* is a Judith River type and is vastly older than the Arapahoe. The fragmentary nature of the fossil precludes accurate determination. The type of *Triceratops galeus* is also from the Arapahoe, but Mr. Hatcher has rejected the species on the ground of inadequate material.

From the Denver two species are reported, one referred by Marsh provisionally to *Triceratops horridus*, which may be correct; the other, the type of *Triceratops alticornis*, by far the most notable ceratopsian from this locality. This specimen was found by Mr. Cannon in the rocks of the largest of the tributaries, which rises on the eastern slope of Green Mountain and enters the Platte River near the Larimer Street Bridge, Denver. The exact locality was about 1 mile from the mouth of the smaller stream.

RELATIONSHIP OF THE BLACK BUTTES, CONVERSE COUNTY, AND DENVER BEDS.

Stanton and Knowlton[a] thus summarize our knowledge concerning the relative age of the "Ceratops beds:"

Until a few years ago it was the custom to include in the Laramie all of the beds between the Fox Hills and Wasatch formations. In the Denver region the detailed studies of Cross and Eldridge . . . have resulted in the recognition of the Arapahoe (Willow Creek) and Denver beds separated from the Laramie and from each other by unconformities and distinguished by marked lithologic features. A revision of the fossil floras of that region has also shown that the Denver beds contain a flora composed of species a large proportion of which are not found in the underlying Laramie. . . .

The Denver and Arapahoe beds have yielded representatives of a remarkable reptilian fauna consisting largely of horned dinosaurs of the family Ceratopsidæ. The presence of this family in the Ceratops beds of Converse County and probably at Black Buttes has suggested the very reasonable query whether the beds containing them at these places also are not younger than the true Laramie. The facts we have presented relative to the stratigraphy and paleontology of the Black Buttes dinosaur horizon seem to us convincing that it is in the Laramie and near the base of that formation. It is less than 200 feet above the marine Cretaceous, and there is no evidence of a break nor of any abrupt lithologic change. The character of the flora and of the invertebrate fauna also, so far as the species have a distribution in recognized horizons elsewhere, favors its reference to the Laramie. If the dinosaur bed of Black Buttes is not Laramie, then the Laramie is either absent or is represented only by about 100 feet of sandstone. The overlying beds up to and including strata with a Fort Union flora seem to form a continuous series that is indivisible either structurally or lithologically, and we can see no reason for placing the top of the Laramie lower than the base of the lowest bed with a Fort Union flora.

Closely similar conditions are seen in Converse County, the principal difference being a greater development of the beds. The sandstones at the base, overlying the Fox Hills, are a few hundred feet thick, and the variable more argillaceous, higher

[a] Bull. Geol. Soc. Am., vol. 8, p. 155.

beds, with a fresh-water fauna in large part identical with that at Black Buttes and a flora that also indicates the same horizon, have a much greater thickness. Here again there seems to be no break in a series that has Fort Union plants in its upper member. The abundant occurrence of such a species as *Campeloma multilineata* throughout all but the lowest portion of the series argues strongly for continuous sedimentation.

The difficulty of recognizing unconformities in beds so little disturbed and the possibility that there may be such undiscovered breaks in these two areas is freely admitted, though it does not seem to us probable. From the facts now available it seems most probable that in Converse County and in the Bitter Creek Valley the time representatives of the Denver and Arapahoe beds are undifferentiated portions of a continuous series and can not be separated from the Laramie. The Fort Union beds are apparently distinguishable by means of their flora, and these mark the upper limit of the Laramie in the areas in question.

The *Triceratops* skulls from Hell Creek represent species whose position stratigraphically is about the middle of the Converse County series of specimens, which is evidence in favor of considering the former deposits as contemporaneous with the latter.

Geological sequence of the Ceratopsia.

Formation.	Locality.	Species.
Denver	Near Denver, Colo	Triceratops alticornis. ? Triceratops horridus.
Arapahoe	Near Denver, Colo	Triceratops alticornis. Triceratops galeus.[a] ? Ceratops montanus.[b]
Laramie	Lance Creek beds, Converse County, Wyo.	Torosaurus latus. Torosaurus gladius. Diceratops hatcheri. Triceratops elatus. Triceratops flabellatus. Triceratops brevicornus.[c] Triceratops sulcatus and calicornis. Triceratops serratus.[c] Triceratops prorsus. Triceratops horridus. ? Triceratops obtusus.
	Near Black Buttes Station, Wyoming.	Agathaumas sylvestris.
Fox Hills		No Ceratopsia.
Bearpaw		No Ceratopsia.
Judith River beds	Near Judith, Mont	Ceratops montanus. Ceratops paucidens. Monoclonius crassus. Ceratops recurvicornis. Monoclonius sphenocerus.[d]
	Red Deer River, Alberta[e]	Centrosaurus apertus.[f] Ceratops canadensis.[f] Monoclonius dawsoni.[g] Ceratops belli.[h]

[a] Species rejected by Hatcher because of the fragmentary condition of the type.
[b] This form is placed among the Arapahoe Ceratopsia by Whitman Cross on page 230 of the monograph on the Geology of the Denver Basin (Mon. U. S. Geol. Survey, vol. 27). It must be a case of mistaken identity (see p. 183 of this monograph).
[c] Also Hell Creek, Montana.
[d] Horizon not recorded.
[e] Belly River beds. The Montana and Alberta species were contemporaneous.
[f] From upper beds.
[g] From middle beds.
[h] From lower beds.

Although the formations above the Fox Hills have been placed in regular sequence in the above table, it may be that the Ceratopsia-bearing strata in Converse County include the equivalents of those near Denver.

COLLECTING CERATOPSIAN MATERIAL.

In the chapter of the present memoir devoted to the history of discovery reference is made to the various expeditions which have searched for these interesting forms. While not the pioneer ceratopsian collector, Hatcher brought to light by far the major part of all of the known material pertaining to this group. His work was mainly among the larger genera of the Laramie, especially in the Converse County locality, and his experience was such that he could have written a most interesting and instructive chapter upon the difficulties and dangers incident to the collection of such huge fossils.

In one specimen collected in Converse County by Hatcher the concretion containing the skull weighed 6,850 pounds when received at the Yale Museum. This is by far the largest specimen of *Triceratops* yet found, having an estimated length of 8 feet from the tip of the rostral bone to the hinder margin of the frill. In the same concretion were many other bones and a large fragment of vegetable origin, further evidence in favor of Hatcher's conception of the habitat of the Ceratopsia.

The present author's experience in the field in search of Ceratopsia, though limited to a single eventful season, was of such a nature as to present a full measure of experience from the variety of conditions met with. This expedition will be taken as an illustration of field methods and the problems to be solved.

During the summer of 1902 Mr. Barnum Brown, of the American Museum of Natural History, accompanied by the author, was sent into the northern part of Montana to explore a new locality for Laramie dinosaurs. The locality was made known to Professor Osborn through Mr. William Hornaday, director of the zoological gardens in Bronx Park, New York, who, in company with Mr. L. A. Huffman, a photographer, of Miles City, Mont., had taken a trip up into the Hell Creek region the season before. While there these gentlemen found a ceratopsian horn core, which showed that there were prospects of finding these fossils in this locality.

The great majority of the Laramie Ceratopsia found by Hatcher were incased in hard sandstone concretions, which, while vastly increasing the weight of the specimen and the difficulty both of collecting and of subsequent preparation for exhibition and study, generally insured its preservation from destruction by the action of the elements. As many of Hatcher's finest specimens had already weathered out of the bank in which they had been embedded, the importance of this fact can readily be imagined.

Our party found no fewer than thirteen skulls, but all of these except one had entirely disintegrated, and the portion of this one that protruded on the surface of the ground was destroyed. This specimen was in unconsolidated sandstone; another was in joint clay; while a third fossil, not a ceratopsian, was inclosed in concretions and gave us a very perfect idea of such collecting. As each of these three matrices presented its special problems for solution, they will be described in some detail.

At quarry No. 1, that opposite the camp, a specimen of a huge carnivorous dinosaur (*Tyranosaurus rex* Osborn) was found embedded in a number of separate concretions. The largest of these was but partially buried, and from the exposed end a broken portion of a huge tibia protruded. By searching down the hill most of the fragments which had been broken away were recovered and afterwards restored to their original position. The excavation of the concretion itself was easily accomplished, but it was far too heavy for shipment, and the work of reducing it to a more moderate bulk was arduous enough, as the rock was hard and the facilities for sharpening and retempering dulled and broken tools were very crude. The block, which contained a tibia and the coossified pubes, weighed 1,700 pounds when all of the matrix possible was removed, and the task of loading it upon the wagon presented a serious engineering problem. A road was cut along the face of the butte to the little valley which divided it from the neighboring hill, to which place the wagon could be brought. The block, carefully swathed in strips of burlap dipped in liquid plaster to protect the protruding bone, was placed upon an

improvised stone boat and hauled along the road by means of the block and tackle and one of the heavy horses.

When the load reached the wagon the latter was run into two parallel trenches, so as to bring the wagon bed on a level with the ground, when the specimen was hauled into the wagon with comparative ease. The other concretions were all smaller than the first, most of them containing a single vertebra or one or more small bones, but the deeper lying ones were extremely hard, being composed of a perfectly homogeneous bluish sandstone, and had to be removed bodily to New York, where better tools were available, before their final reduction could be accomplished and the contained bones freed from their matrix.

Our first *Triceratops* specimen (quarry No. 2), consisting of vertebræ, ribs, the sacrum, the lower jaws, and a few limb bones, lay in a peculiar joint clay of a bluish color, though occasionally stained a rusty brown along the joints. The bones were poorly preserved, presenting in this respect a marked contrast with the admirable condition of those of the carnivore, as the joints in the clay ran through the bones as well, which therefore required the most delicate manipulation. The process consisted in the removal of the overlying material, first with a heavy pick and spade, a process technically known as "stripping," then with a light prospector's pick, and finally with a harness awl and whisk broom. The exposed bone surface was then treated with a solution of gum arabic to harden it and then covered, first with tissue paper and finally with strips of burlap dipped into flour paste. The bones were then excavated still farther, the exposed surface being covered as before, and finally were lifted from their age-long bed and the lower side treated in the same manner. While the smaller bones were now ready for packing, the larger ones had to be provided with a plaster of Paris jacket, sometimes with splints of wood for further support, just as a surgeon prepares a broken limb. The bones were then packed in hay in heavy boxes ready for shipment.

Quarry No. 3 contained the great skull of *Triceratops serratus*, No. 970, before referred to and figured in this monograph (fig. 26, p. 29). This was found, together with some limb and foot bones, about 1 mile down Hell Creek from the camp, and presented a third aspect of Laramie collecting.

The specimen in this instance was in unconsolidated sandstone, the skull lying in normal position, with the supraorbital horn cores protruding on the surface and sustaining an abundant growth of vegetation, which aided largely in the disruption of the bone.

The nasals, with their horn core, were eroded away, and the small rostral bone lay displaced on the right side of the snout, while one complete dentary, with perfect dentition, and other portions of both jaws lay beneath the skull, as though still attached by ligaments when the specimen came to its last resting place. As is usual with Ceratopsian skulls, the upper teeth had almost entirely disappeared, which leads one to believe that the huge head must have had great powers of flotation, owing to the cavities in which the expansive gases incident to decay could develop, and was as a consequence probably the last portion of the creature's frame to become buried in the sand.

Our specimen was in fine condition where it was completely buried, though extremely fragile, and the process of excavation was carried out with the utmost caution, the exposed portions being covered at once with plaster bandages to guard against possible injury.

As the broad expanse of frill, measuring in this instance 5 feet in width by nearly 3 feet in length, would not bear its own weight, it was supported from beneath by vertical props as fast as the earth was removed. It was decided to retain the matrix under the palatal portion of the skull for safety's sake, so it was necessary to spray this repeatedly with gum arabic solution, which hardened it, so that it was self-sustaining. The under side of the frill was then plastered, and by occasional tunneling the matrix was bound fast to the skull by means of the burlap strips. Next a complete trestlework was built of scantling underneath the entire structure, and the whole was bound fast with the plastered strips, so that the resultant fabric was extremely solid. The box, which was built beneath and around the specimen without disturbing it in the least, was ~~of the smallest possible dimensions, yet measured 7 feet in length by 5½~~ feet in breadth, and about 4 feet in depth, and weighed, with its contents, 3,100 pounds.

The skull location was on the extreme point of a divide between Hell Creek and one of its tributaries, with a precipitous descent on either side, so that here again it became necessary to construct a roadway along the edge of the canyon wall to the broader part of the divide above, to which the wagon could be driven. The tackle and horse were used, as before, boards being this time laid along the roadway, with small logs for rollers. Even with a large, wide-gage wagon it was necessary to remove the wagon box, as it could not possibly contain the specimen. Three trunks of trees were laid on the fully extended wagon frame, which was backed up to a convenient bank, on which the hinder end of the logs rested. It was then found that the skull box was too wide to pass between the rear wheels, so they were undermined, and thus lowered beneath the level of the logs. The box was then slid into position with little difficulty, the hind axle was raised with a lifting jack, and earth was thrown beneath the wheels until they again bore the load. The protruding tree trunks were then sawed off, the specimen box was lashed fast to the wagon, and the task of loading was thus completed. The skull was hauled out to Miles City, a distance of 135 miles, whence it was shipped directly to New York.

PROBABLE APPEARANCE, HABITS, AND ENVIRONMENT OF THE CERATOPSIA, AND THE CAUSES THAT LED TO THEIR EXTINCTION.

EVOLUTIONARY SUMMARY.

The earliest known Ceratopsia are from the Judith River beds, and the race continues upward until the close of the Cretaceous period, during which time it underwent a striking evolution, largely one of size and armament.

Of the ancestors of the Judith River forms we have no record, probably because, as Matthew believes (see p. 194), they were dry-land types, notwithstanding the swamp-living habits of their successors.

The Judith River ceratopsians already exhibit the characteristic horns and frill, but the relative proportions of nasal and supraorbital horn cores are the reverse of those of the Laramie types. The nasal horn was the first to develop. It varied somewhat in form, being straight and compressed in *Monoclonius sphenocerus* and curved strongly backward in *M. dawsoni*. In the other Judith River genus, *Ceratops*, it seems to have curved forward instead of backward, and the supraorbital horn cores, which were rudimentary in *Monoclonius*, are much more advanced in development, though the nasal horn was in all probability still the larger. The frill in the Judith River types is by no means so well developed as in the Laramie forms, and in *Monoclonius* and *Centrosaurus* consisted largely of the coalesced parietals, the squamosals taking but little part in its formation, but in *Ceratops*, though the crest still consists mainly of the widely fenestrated parietals, the squamosals become a more prominent factor, tending toward the form of the latter bone found in *Torosaurus*.

There is evidence that the teeth of the Judith River forms were somewhat more primitive than those of the later Ceratopsia in that the peculiar method of replacement was not fully assumed in the earlier types.

The stratigraphical range from the Judith River beds to those containing the earliest Laramie type, disregarding for the moment *Agathaumas*, is 3,500 feet according to Hatcher's estimate (p. 119). This implies a great lapse of time, during which the most striking evolutionary changes occurred, so that *Triceratops horridus*, the earliest recorded Laramie species, exhibits a marked advance in cranial features over its Judith River predecessors. Here the supraorbital horn cores are vastly larger, while the nasal horn is much reduced, tending to disappear almost entirely in *T. obtusus* or *Diceratops*. Correlated with this change of offensive armor is an increased development of the defensive frill, which in *Triceratops* is no longer fenestrated, though in *Torosaurus* it still retains large paired fontanelles in the parietal portion of the crest.

The advance in the structure of the Laramie types seems, therefore, to lie in (1) *the larger size of the individuals*, (2) *the preponderance of the supraorbital horns over the nasal*, (3) *the more perfectly developed parietal crest*, and (4) *the perfection of the type of dentition peculiar to the group.*

Agathaumas, from the lower Laramie, is known only from certain portions of the skeleton and seems to be transitional between *Monoclonius* and *Triceratops*, while *Triceratops alticornis*, from the Denver beds and therefore the most recent of all, exhibits a type of supraorbital horn core which may readily be considered the final stage in the evolution of these weapons.

In the table of stratigraphical sequence (p. 184) the relative positions of the various type specimens are given, except where the level is unrecorded. The phylogenetic series corresponds approximately with the stratigraphic sequence, although of the two *Torosaurus* species Hatcher distinctly states that *gladius* "represents the extreme development of that type of parietal peculiar to this genus," thereby implying that *T. gladius*, which is geologically the older, is the more specialized of the two.

PROBABLE APPEARANCE OF THE CERATOPSIA.

THE JUDITH RIVER TYPES.

Our knowledge of the general form of the earlier Ceratopsia is still very vague, for with the exception of *Monoclonius crassus*, among Judith River types, most of the remains are of incomplete skulls only.

But two attempts have been made to restore Judith River forms, consisting of a statuette and a painting, both by Charles R. Knight. The restorations, which differ somewhat from each other, have been called *Agathaumas sphenocerus*, the supposition being that *Monoclonius* and *Agathaumas* were synonymous genera, the latter term having priority. The restoration is really that of *Monoclonius sphenocerus* Cope.

The statuette, the property of the American Museum of Natural History, is figured as Pl. I, fig. 1, in the Catalogue of casts, models, photographs and restorations of fossil vertebrates, by Professor Osborn,[a] 1898. The painting, also in the American Museum, was reproduced in the Century Magazine[b] for November, 1897.

The conception of the tall, straight nasal horn and the much smaller supraorbital horns is undoubtedly correct, though in *Monoclonius sphenocerus* the compressed nasal horn slants somewhat backward, while in other species of the genus it *curves* to the rear. The writer questions whether the hinder margin of the frill was quite so prominent as it is represented in the model and painting, for in the earlier types the whole crest is much less strongly developed than in the later forms, and although the edge is crenulated yet there is little reason to suppose that the marginal armature was as well developed as it appears to be in the restoration. The general bodily proportions are based upon "a reconstruction of a possibly identical and prior restoration of *Triceratops prorsus* (Marsh)" (Ballou). It is now known that Marsh was in error in making the presacral series of vertebræ too numerous in his restoration of *Triceratops* (fig. 125), hence the probabilities are that here again the back is unduly elongated, though of this we have no positive knowledge.

The Judith River Ceratopsia were smaller than their Laramie successors, and of lighter and less muscular build, and from the development of cranial armature differed in their offensive and defensive tactics.

It is difficult to conjecture in what way *Ceratops* would differ in external appearance from its contemporary *Monoclonius* except in the much greater development of the supraorbital horns. The nasal horn core is unknown except in one species, *Ceratops* (*Monoclonius*) *recurvicornis* Cope, in which it curves strongly forward, in contrast to that of *Monoclonius*. As this species differs from the others that Hatcher refers to *Ceratops* in an important anatomical feature—namely, in the presence of separately ossified epoccipital bones—the present writer is loth to consider it as typical of the genus, if, indeed, it belongs with *Ceratops* at all.

There are no data concerning the bodily proportions or contour of *Ceratops*.

[a] See also Science, vol. 7, p. 842, fig. 1.

[b] Ballou, W. H., Strange Creatures of the Past, p. 18.

THE LARAMIE TYPES.

Marsh has given us the first skeletal restoration of *Triceratops* in the Sixteenth Annual Report of the United States Geological Survey (Pl. LXXI), reproduced here as fig. 125.

This restoration is very accurate except for the number of presacral vertebræ, which has been overestimated. As Hatcher has shown, in *Triceratops brevicornus* at least (p. 46, fig. 48), the number of presacrals is not more than twenty-two, while in Marsh's figure there are twenty-one *without* the cervicals, which probably number at least eight more. Another feature about which doubt may be expressed is the correctness of the restoration of the feet, for while odd foot bones have been brought to light, no complete manus or pes of this interesting animal has yet been found.

Knight has essayed at least three restorations of *Triceratops*, the first two, a statuette and a drawing, being based largely, if not wholly, upon that of Marsh. The statuette was made for the American Museum, and a view of it is shown as fig. 26 in F. A. Lucas's Animals of the Past (McClure, Philips & Co., New York, 1901), while the drawing was also published by Lucas.[a]

The restoration of *Triceratops* which forms the frontispiece of the present volume was made under Hatcher's personal supervision, and is one of the most successful of Knight's artistic reconstructions. The general proportions are markedly different from those of the preceding conceptions of the animal, notably in the shortening of the back and in placing the highest point in the arch of the vertebral column over the sacrum rather than farther forward. The proportion of head to trunk is also greater, the skull being almost one-third of the entire length of the animal, including the tail. The length of the tail is conjectural, as a complete caudal series is unknown and it is possible that it may have been reduced somewhat, as it no longer subserved the function of a counterpoise, as in bipedal dinosaurs.

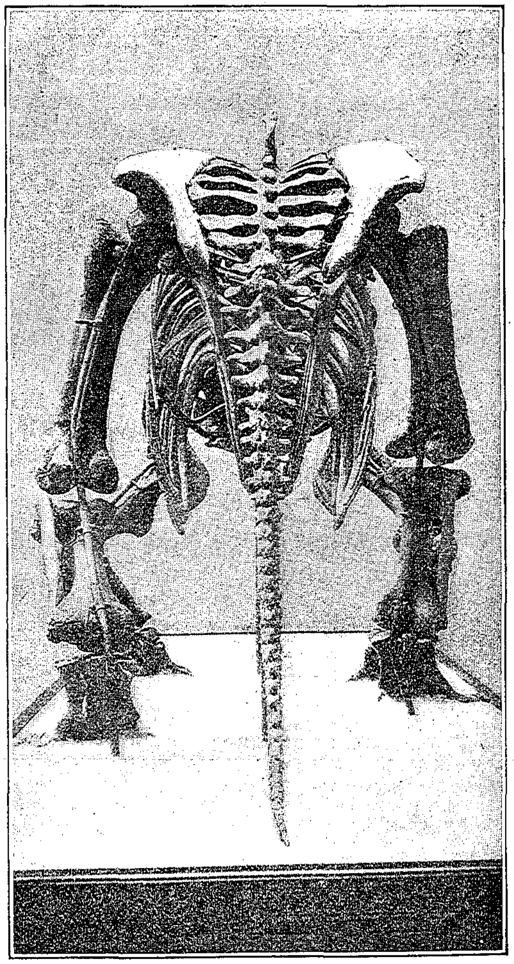

FIG. 124.—Restoration of *Triceratops*. Rear view of the mounted skeleton in the U. S. National Museum. (See also Pl. XLIX.)

The skeleton of *Triceratops prorsus* which has recently been mounted at the National Museum is that upon which Marsh based his restoration, and a comparison of the results is of great interest. The skeleton was mounted by Mr. C. W. Gilmore, of the Museum staff, and his description of the specimen is here given:[b]

> The skeleton of *Triceratops prorsus*, recently placed on exhibition in the court devoted to vertebrate paleontology, is the first one of this extinct genus to be mounted. As all of the specimens [of Triceratops] referred to above were more or less fragmentary, the most complete one (No. 4842[c]) [Sk. C, 2082 and 2084[d]] was used as a basis for the present restoration. The missing parts [including the skull (No. 2100)] were substituted from other individuals of about the same size and belonging to the same species. Where suitable bones were not available, as was the case in a few instances, these parts were restored in plaster, colored to somewhat resemble the bones, but having the shade differ sufficiently to be easily recognized. Thus we have been able to present a fairly accurate representation of the skeletal structure of this peculiar reptile. Every bone used in

[a] Ann. Rept. Smithsoni n Institution for 1901, p. 644, Pl. I.

[b] Gilmore, C. W., A mounted skeleton of Triceratops: Proc. U. S. Nat. Mus., vol. 29, 1905, pp. 433–435. Some words in brackets have been since added by Mr. Gilmore.

[c] Catalogue number of the U. S. National Museum.

[d] Marsh's original numbers.

the skeleton bears its catalogue number, and all plaster bones are marked with a red +. There is thus preserved a definite record of all the associated material comprising the composite skeleton. * * *

The skeleton as mounted is standing on a base of artificial matrix intended to represent the color and texture of the Laramie sandstone in which the remains of these animals are found.

From the tip of the beak to the end of the tail the skeleton as restored is 19 feet 8 inches in length. The skull, which is 6 feet long, equals nearly one-third of this length [a remarkable proportion]. At the highest point (the top of the sacrum) the back is 8 feet 2 inches above the base. The mounted skeleton presents several features which would otherwise be lost to the observer if seen in the disarticulated condition. The short body cavity, the deep thorax, the massive limbs, and the turtle-like flexure of the anterior extremities are characters appreciated only in the mounted skeleton. The position of the forelimbs in the present mount appears rather remarkable for an animal of such robust proportions, but a study of the articulating surfaces of the several parts precludes an upright mammalian type of limb, [such] as was represented by Marsh in the original restoration. * * * The [tail and] forefeet are perhaps the most conjectural parts of the whole restoration. [The tail is restored almost wholly from Marsh's drawing of this animal.] Mr. Hatcher, after a careful study of all the forefoot material [of this group] known, was unable to arrive at a satisfactory conclusion as to the arrangement or the number of bones comprising the manus. In constructing these parts we have largely followed Marsh's drawing, assisted somewhat by forefoot material kindly loaned by Dr. H. F. Osborn, of the American Museum of Natural History, New York City. [It seems probable that a similar condition prevailed in this animal to that found in the other better known dinosaurs, so instead of introducing a full complement of carpal and tarsal bones, as was done in the first restoration, only two elements were modeled to represent the carpus, while the astragalus alone comprises the tarsus.]

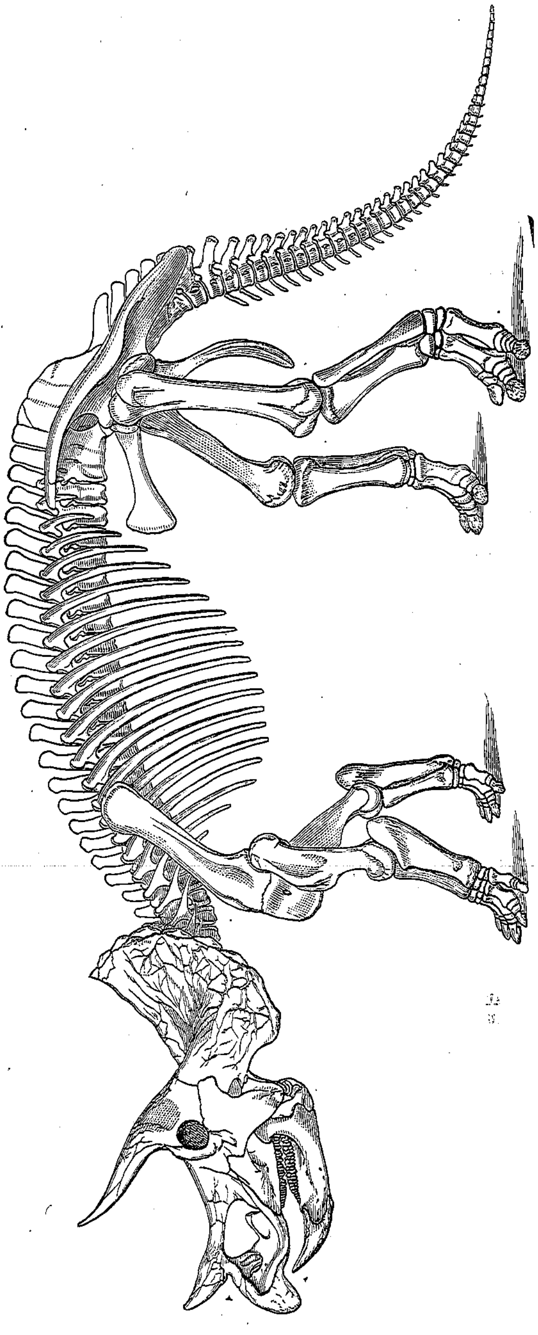

FIG. 125.—Restoration of *Triceratops prorsus*. After Marsh.

The nasal horn [core] of the skull used in the present skeleton appears to be missing, and on account of the unsatisfactory evidence as to whether the horn is wholly or only partly gone, it was decided not to attempt a restoration at this time. This will account for the absence [or rather the apparent lack of development] of one of the important features upon which the name of the animal is based, *Triceratops* meaning three-horn face, in allusion to the presence of the two large horns above the eyes and a third smaller horn on the nose.

It may be of interest to mention here that Professor Marsh used this skeleton (No. 4842), supplemented by other remains now preserved in the collections of the Yale University Museum, for the basis of his restoration of *Triceratops prorsus*, published as Pl. LXXI in the Dinosaurs of North America [fig. 125].[a] Pls. LXIV–LXVIII in the same work were also largely reproductions of parts of this same individual.

A comparison of the above-mentioned restoration by Marsh [fig. 125] with the mounted skeleton [Pl. XLIX of this work] shows several differences in points of structure, due chiefly to the better understanding of these extinct forms. The most striking dissimilarity is in the shortening of the trunk by a reduction of the number of presacral vertebræ. Marsh's error was due to an overestimate of the length of this region, a mistake also made in his restoration of *Brontosaurus* (=*Apatosaurus*), as has been shown by Riggs.[b] Mr. Hatcher determined from a well-preserved vertebral column in the Yale University Museum the number of presacrals as twenty-one,[c] this being six less than was ascribed to the animal by Professor Marsh.

[a] Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 1, p. 386.

[b] Science, new ser., vol. 17, March 6, 1903, pp. 393–394.

[c] Doctor Lull now recognizes twenty-two presacrals (see p. 47).

[In mounting this skeleton an attempt was made to embody all of the discoveries and changes resulting from Mr. Hatcher's thorough study of the Ceratopsia, which he freely communicated in advance of publication. It must be understood, however, that there are still many undetermined points in the anatomy of this group, and the present writer, who mounted the skeleton with the able assistance of Mr. Norman Boss], alone must be held responsible for any anatomical inaccuracies that may be detected in the reconstruction.

One of the most notable features in this skeleton is the great breadth of the pelvis and hind quarters. This impresses one most when the skeleton is viewed from the rear, and is a strong point of contrast between the Ceratopsia and other Dinosauria. (See fig. 124.) This is in the main due to the position of the expanded blades of the ilia, which are horizontal rather than vertical, as in other dinosaurs. The body is so broad that the creature is much better proportioned than one would be led to expect from viewing the skull alone.

Measurements of the mounted skeleton.

	Meters.
Length, following the curve of the vertebral centra (about)	7.25
Skull:	
Length, entire	1.88
Length from condyle to tip of restored rostral	1.10
Length from posterior margin of frill to nasal horn	1.46
Breadth of frill	1.31
Breadth of orbits	.42
Distance between tips of supraorbital horns	.83
Length of right supraorbital horn core from upper edge of the orbit	.70
Girth of horn core just above the orbit	.66
Vertebral column:	
Length of four coalesced cervical vertebræ	.415
Length of entire cervical series	.88
Length of dorso-lumbar series	1.725
Length of sacrum	1.10
Length of restored caudal series	2.41
Breadth of thorax	1.15
Depth of thorax (to lower end of ribs only)	1.525
Length of longest rib (measured along the curve) from tubercle to end	1.45
Length of capitulum to tuberculum	.24
Breadth of sacrum	.64
Breadth of entire pelvis	1.24
Right fore limb:	
Length of scapula and coracoid	1.35
Length of coracoid only	.38
Breadth of coracoid	.39
Breadth of blade of scapula at upper end	.26
Greatest breadth of scapula	.36
Length of humerus	.71
Breadth of proximal end	.40
Breadth of distal end	.36
Girth of shaft	.43
Length of ulna	.65
Breadth of proximal end	.38
Breadth of distal end	.19
Girth of shaft	.36
Length of radius	.41
Breadth of proximal end	.18
Breadth of distal end	.14
Girth of shaft	.205
(NOTE.—As the manus is entirely restored no measurements were taken.)	
Right hind limb and pelvis:	
Length of ilium	1.50
Greatest depth (to ischiac peduncle)	.32
Breadth of blade	.32
Length of pubis	.85
Breadth at anterior end	.28

	Meters.
Right hind limb and pelvis—Continued.	
Length of ischium (measured on outer curve)	1.50
Breadth of proximal end	.40
Length of femur	1.15
Breadth of proximal end	.42
Breadth of distal end	.43
Girth of shaft	.485
Length of tibia and astragalus	.72
Breadth of proximal end of tibia	.395
Breadth of distal end of tibia	.39
Fibula (restored)	
Length of metatarsal II	.29
Length of metatarsal III	.355
Length of digit III	.325
Length of ungual phalanx IV	.11
Breadth of ungual phalanx IV	.12
Measurements depending on posture:	
Height to summit of back	2.47
Breadth of shoulders at glenoid fossæ	1.25
Breadth of elbows	2.16
Breadth across outer digits	1.70
Breadth across heads of femora	1.50
Breadth across knees	1.93
Breadth across outer digits	2.04

This skeleton has been admirably prepared and mounted by Mr. Gilmore. Two points, however, are open to question, as is clearly recognized by Mr. Gilmore—the position of the skull and that of the ischia.

In the skull here mounted, as well as in the skulls of the type of *Diceratops hatcheri*, of *Triceratops calicornis*, and of other species of *Triceratops*, the condyle, which is supported on a neck, is strongly deflected downward in such a way as to cause the head to be carried low in front if the line of the condyle is continuous with that of the cervicals, which it evidently should be. The hemispherical articulating surface of the condyle is of such extent that the head might have been raised to a somewhat higher position than that given it in the mount or, on the other hand, depressed until the beak reached the ground, but the average position would be with the muzzle about 20 inches (0.51 m.) lower than in the mounted position. In the ischia the articulating extremities are of such a character that their exact method of union with the ilia and pubes is highly conjectural, and further evidence from other specimens may necessitate a radical departure from their position in the present mount.

It seems probable that four is the correct number of digits in the manus rather than five as in the mounted specimen.

The cranial armature at once shows a sharp contrast in development and in mode of use with that of the ancestral *Monoclonius*, for in *Triceratops* the frill was complete and heavy and undoubtedly flared upward and outward to a greater extent than in the former genus, affording not only leverage for muscular attachment, but, as a helmet-like structure, serving to protect the neck region from the horns of the adversary. In *Triceratops*, too, the temporal horns are large and are strongly curved forward, with a corresponding reduction of the forward-directed nasal horn. The restoration (Pl. I, frontispiece) expresses well the appearance of the lowered head, in which all three horns are brought to bear against the enemy at the moment of impact. In *Monoclonius* the offensive stroke must have been an upward thrust in which the erect or backward-curved nasal horn would prove a most efficient weapon, while *Triceratops* would charge with lowered head, seeking either to impale his enemy or to bear the latter down by the impetus of his great weight.

The expansion of the frill and the development of great protecting ridges around the orbit would be such as to best protect the most vital points, the neck and the eyes, from such a mode of attack.

Triceratops was extremely deficient mentally, and was probably of comparatively peaceable disposition except, perhaps, at the breeding season. Then the combats between rival males which probably took place must have been prompted and carried out by blind, unreasoning instinct solely. This would make such weapons and defensive armor very efficient, for the Ceratopsia were evidently not intelligent enough to use weapons requiring skill in their manipulation.

The question of other skin protection can not yet be settled, for while certain dermal scutes and ossicles have been found which may have been borne by *Triceratops*, we have no knowledge of their position or arrangement. It is unreasonable to suppose that the skin was naked, for such condition is found only among exclusively aquatic reptiles, such as the ichthyosaurs.

The limbs were doubtless somewhat elephantine except that the ulna, with its huge olecranon process, gives evidence of having been flexed to a greater degree, as shown in the restoration.

Of the feet we have but little trustworthy knowledge. The hoof-like claws are clearly indicated by the form of the ungual phalanges and, if Hatcher's very reasonable conception of the creature's habitat be correct, one would expect a somewhat spreading foot, which would bear the animal up in soft ground.

Of *Triceratops* only have we any idea of general form and proportions, its contemporaries *Diceratops* and *Torosaurus* being known only from the skull.

Diceratops, it will be remembered, had no nasal horn, and the supraorbitals were erect instead of forward projecting as in *Triceratops*. Its mode of fighting must have differed somewhat from that of the latter, probably in lowering the head much more. The peculiar fenestræ in the squamosals are unequal in size, and the one in the right parietal, near the margin of the frill (the corresponding portion of the left having been destroyed), may have been due to wounds caused by the penetration of an adversary's horn. In the Yale Museum there is a scapula of *Diclonius* with a clean-cut perforation, the edges of which have healed so as to give the appearance of a normal foramen. It is absent in the other scapula of the same animal, and Professor Marsh used to say that it was made by the horn of a *Triceratops*. This is certainly very suggestive of the *Diceratops* fenestræ. The left squamosal of the type of *Triceratops elatus* also shows a perforation near the parietal suture, which is of pathologic character. (See Pl. XLIII, p. 284.)

In *Torosaurus* the cranium was of proportions so different, with its immense though weak frill and its wedge-shaped facial region, that the aspect of the head must have differed greatly from that of *Triceratops*. The upper surface of the frill does not bear the deep vascular impressions of the last-mentioned genus nor are there marginal ossicles, indicating that instead of being somewhat free with a dense horny or tegmentary covering, the crest was more or less buried in the flesh of the neck. It was evidently used to obtain leverage for the head and not like the neck guard of a helmet, to protect the cervical region. The presence of the large vacuities is further evidence in favor of this belief. The two known species of *Torosaurus* are huge creatures, larger than the average *Triceratops* though of less proportions than the giant specimen of the latter genus alluded to on page 185. The supraorbital horns of *Torosaurus* were well developed, though the nasal horn was proportionately reduced and acutely pointed.

PROBABLE HABITS.

The feeding habits of the Ceratopsia are manifest from the tooth structure and from the character of the vegetation preserved with ceratopsian remains. The forward part of the mouth was edentulous and was sheathed on both the upper and the lower jaw, with a cutting beak like that of a turtle. Within the mouth were the magazines of teeth, each series presenting a vertical though slightly twisted wearing surface toward that of the opposing series, the worn surface of the lower teeth facing outward, that of the upper row inward. There is no possibility of a lateral grinding movement, as in herbivorous mammals; the lower jaw must have been moved entirely in a vertical plane. The beak probably served for cropping the more succulent leaves and shoots of low trees or shrubs, while the teeth were used to chop the food into short pieces before it was swallowed. As such pieces would naturally fall outside of the teeth of the

lower jaw, the food must have been retained within the mouth by the muscular walls of the cheeks. Unless the teeth also subserved the function of food getting as well as of mastication, which is questionable, it is doubtful whether the gape of the mouth had a greater backward extent than the anterior end of the tooth series. This would bring the corner of the mouth decidedly in advance of the position indicated by Knight in Pl. I. (Compare fig. 5.)

PROBABLE ENVIRONMENT.

T. W. Stanton in a note[a] says:

It is difficult to reconstruct the physiographic conditions which prevailed in the Middle West during later Mesozcic time, but it should be remembered that in that region there was then a great shallow continental or mediterranean sea, and that there were large areas so near sea level that very slight movements would bring them beneath the sea or partly or wholly drain them, so that it is probable that shallow-water and nonmarine conditions were often extended over large areas very rapidly.

It would seem as though some such elevation, occurring at the close of the Claggett, gave rise to conditions under which the fresh-water Judith River deposits could be formed and that the Judith River period was succeeded in turn by a subsidence which caused an encroachment of the sea upon the land, giving rise to the Bearpaw shales. Next a second diastrophic movement caused a recession of the salt waters and inaugurated the conditions which characterized the Laramie.

Hatcher[b] thought that the period of elevation which brought about the close of the marine Cretaceous was followed, during the Laramie, by a period of subsidence not sufficient to cause a return to marine conditions, but such as to allow continual shallow-water deposition, as is evidenced by the great number of lignite seams in the Ceratops beds and by the absence of continuity of strata and the frequent cross-bedding which prevailed. Hatcher says:

The Ceratops beds are thought to afford evidence in themselves of having been deposited not in a great open lake, but in a vast swamp, with occasional stretches of open waters, the whole presenting an appearance similar to that which now exists in the interior of the Everglades of Florida. This condition would account for the frequent changes from one material to another in the same horizon. . . . In some places in the beds these changes are quite frequent, strata of sandstones and shales replacing one another in great confusion. It would also explain the cross-bedding so often seen in the sandstones of this region, in localities remote from the present border of the beds, and hence far removed from the shore of the ancient lake or swamp. This cross-bedding could hardly occur in offshore deposits of a great fresh-water lake of any considerable depth.

The conditions that prevailed over this region during the period in which the Ceratops beds were deposited were probably those of a great swamp with numerous small, open bodies of water connected by a network of watercourses constantly changing their channels. The intervening spaces were but slightly elevated above the water level or at times submerged. The entire region where the waters were not too deep was covered by an abundant vegetation, and inhabited by the huge dinosaurs (*Triceratops*, *Torosaurus*, *Claosaurus*, etc.), as well as by the smaller crocodiles and turtles and the diminutive mammals, all of whose remains are now found embedded in the deposits.

The frontispiece admirably depicts such a scene as Hatcher has described.

Dr. W. D. Matthew,[c] in a recent paper, speaks of three modes of life available during the Mesozoic for land vertebrates, "the amphibious-aquatic, the arboreal, and the aerial, the terrestrial being subordinate because the upland flora was largely undeveloped or inedible as compared with its present condition." The three provinces Matthew believed were peopled by reptiles, mammals, and birds respectively. With reference to the dinosaurs in particular Matthew's views are expressed in a letter to the writer, dated June 6, 1905, as follows:

I believe that they (the dinosaurs) were a—in fact the—land group of reptiles, but that nearly all we know of them is a number of aberrant amphibious or aquatic specialized branches; that the great arid subglacial period of the Perm-Trias gave them their initial trend on lines parallel to the evolution of the Mammalia during the Tertiary-Quaternary; that in the late Jura and the late Cretaceous a reaction to moist, torrid climate caused a great expansion and specialization of amphibious swamp-living forms, adapted to the marshy jungles then prevalent.

These are the dinosaurs we know. Of the dry-land forms we know very little. A few Triassic types, possibly some of the Jurassic ones, like *Ornitholestes* and *Hallopus* and *Laosaurus*, and the jungle-living carnivorous types departed less than the others from the primitive dry-land type. The Sauropoda I regard as exclusively water-living—the larger forms at least.[d]

[a] Proc. Am. Philos. Soc., vol. 43, p. 364, 1904.

~~[b] Am. Jour. Sci., 3d ser., vol. 45, 1893, p. 142.~~

[c] Am. Naturalist, vol. 38, Nov.-Dec., 1904, p. 816.

[d] Herein Matthew and Hatcher disagreed, as the latter considered the Sauropoda also as "terrestrial reptiles with amphibious habits, passing much, perhaps most, of their time in shallow water, where they were able to wade about in search of food." The evidence is strongly in favor of Matthew's belief.—R. S. L.

The stegosaurs, claosaurs, and ceratopsians may have been more or less land haunting, but not upland, and they all impress me as amphibious adaptations *from* a type highly specialized for land locomotion.

In the later Cretaceous the terrestrial province was greatly expanded by the development of the upland flora which provided for a corresponding spread of terrestrial types. These were derived mainly from the previously arboreal mammals, the birds maintaining their aerial habitat, while of the reptiles, the lizards and snakes only were able to adapt themselves to these new conditions. At the time of the expansion of the upland realm there was great dwindling of the amphibious-aquatic province, due to the orogenic movements occurring at the close of the Mesozoic, which drained the Cretaceous sea and its adjacent swamps and river deltas and caused the Reptilia to undergo a corresponding diminution.

PROBABLE CAUSES OF EXTINCTION.

Several theories have been advanced as to the probable causes of extinction of the Ceratopsia, some authors maintaining that the horned herbivorous types were in part destroyed by the large carnivorous dinosaurs. There is always, however, a balance in nature, an offsetting of Carnivora or parasitic forms against their plant-feeding contemporaries and, though the latter may have been held in check by the former, it is extremely improbable that strictly contemporaneous forms which have evolved in the same environment could ever exterminate one another. It seems that animals of another race, or hordes of creatures which emigrated from another region, would be more likely to exterminate their predecessors. The mammals fulfill the requirements of a new foe, and the development of the frill in the Ceratopsia has been considered as meeting the necessity for a better protection of the neck blood vessels from the weasel-like attack of small but bloodthirsty quadrupeds. Another notion advanced by Morris and amplified by Cope was that the Cretaceous mammals sought out the eggs of the dinosaurs and destroyed them—Cope even going so far as to suggest the Multituberculata, with their long, sharp anterior teeth, as the probable offenders.

Matthew, however, has given the Mesozoic Mammalia a totally different habitat from that of their dinosaurian contemporaries in the belief recently expressed that the mammals were distinctively arboreal, while we are led to believe that all dinosaurs were either terrestrial or possibly amphibious, the Ceratopsia at least inhabiting the lowlands in a swamp or delta region.

By far the most reasonable cause, and the one which Hatcher himself believed, seems to be that of changing climatic conditions and a contracting and draining of the swamp and delta regions caused by the orographic upheavals which occurred toward the close of the Cretaceous. The Ceratopsidæ and their nearest allies, the Trachodontidæ, both highly specialized plant feeders, were unable to adapt themselves to a profoundly changed environment because of this very specialization, and, as a consequence, perished.

That the Ceratopsia made a gallant struggle for survival seems evident, for they lived through the first series of upheavals at the close of the Laramie and also the second series at the close of the Arapahoe, which were accompanied by great volcanic outbursts in the Colorado region; but the changes accompanying the final upheavals which formed most of the great western mountain chains and closed the Mesozoic era gave the death blow to this remarkable race.

BIBLIOGRAPHY.

American Geologist. [Editorial comment on Dr. G. Baur's "Remarks on the reptiles generally called Dinosauria."] Am. Geologist, vol. 8, 1891, pp. 55–56.

Ballou, W. H. Strange creatures of the past. Century Magazine, vol. 55, 1897, pp. 18, 20–21.

Baur, G. Professor Marsh on *Hallopus* and other dinosaurs. Am. Naturalist, vol. 24, 1890, p. 570.

Baur, G. The horned saurians of the Laramie formation. Science, new ser., vol. 17, 1891, pp. 216–217.

Baur, G. Remarks on reptiles generally called Dinosauria. Am. Naturalist, vol. 25, 1891, pp. 443, 447–448, 452.

Beasley, W. L. A remarkable fossil discovery. Sci. Am., vol. 89, 1903, p. 87.

Bunzel, E. Reptilien der Gosauformation. Abh. Geol. Reichsanstalt, Vienna, 1871, bd. 5, pp. 1–18.

Cope, E. D. On the existence of Dinosauria in the transition beds of Wyoming. Proc. Am. Phil. Soc., vol. 12, 1872, pp. 481–483.

Cope, E. D. Remarks on geology of Wyoming. Proc. Acad. Nat. Sci. Phila., vol. 24, 1872, p. 279.

Cope, E. D. Report on the stratigraphy and Pliocene vertebrate paleontology of northern Colorado. Bull. U. S. Geol. and Geog. Surv. Terr., vol. 1, no. 1, 1874, p. 10.

Cope, E. D. The geological age of the coal of Wyoming. Am. Naturalist, vol. 6, 1872, p. 670.

Cope, E. D. Report on the vertebrate paleontology of Colorado. Ann. Rept. U. S. Geol. and Geog. Surv. Terr. for 1873, 1874, pp. 429–533.

Cope, E. D. Review of the Vertebrata of the Cretaceous period found west of the Mississippi River. Bull. U. S. Geol. and Geog. Surv. Terr., vol. 1, 1874, no. 2, pp. 9–21.

Cope, E. D. The Vertebrata of the Cretaceous formations of the West. Rept. U. S. Geol. Surv. Terr., vol. 2, 1875, pp. 26, 31–41, 53–56, 64–65, 248.

Cope, E. D. Descriptions of some new vertebrate remains from the Fort Union beds of Montana. Proc. Acad. Nat. Sci. Phila., vol. 28, 1876, pp. 248–261.

Cope, E. D. Report on the geology of the Judith River, Montana, and on the vertebrate fossils obtained on or near the Missouri River. Bull. U. S. Geol. and Geog. Surv. Terr., vol. 3, 1877, pp. 565–579.

Cope, E. D. [Review of Prof. L. Lesquereux's contributions to the fossil flora of the Western Territories. Pt. 2, The Tertiary Flora.] Am. Naturalist, vol. 12, 1878, pp. 243–246.

Cope, E. D. The geological record. Am. Naturalist, vol. 14, 1880, p. 511.

Cope, E. D. On the characters of the skull in the Hadrosauridæ. Proc. Acad. Nat. Sci. Phila., vol. 35, 1883, pp. 99–100.

Cope, E. D. The sternum of the Dinosauria. Am. Naturalist, vol. 20, 1886, pp. 153–155.

Cope, E. D. A horned dinosaurian reptile. Am. Naturalist, vol. 22, 1888, pp. 1108–1109.

Cope, E. D. The age of the Denver formation. Science, vol. 13, 1889, p. 290.

Cope, E. D. The horned Dinosauria of the Laramie. Am. Naturalist, vol. 23, 1889, pp. 715–717.

Cope, E. D. Notes on the Dinosauria of the Laramie. Am. Naturalist, vol. 23, 1889, pp. 904–906.

Cope, E. D. [Note on the teeth mentioned by Professor Marsh.] Am. Naturalist, vol. 24, 1890, p. 571.

Cope, E. D. Syllabus of lectures on geology and palæontology. Univ. of Penn., 1891, p. 43.

Cope, E. D. Fourth note on the Dinosauria of the Laramie. Am. Naturalist, vol. 26, 1892, pp. 756–758.

Cope, E. D. Syllabus of lectures on the Vertebrata. Philadelphia, 1898, p. 70.

Cross, Whitman. The Denver Tertiary formation. Proc. Colorado Sci. Soc., vol. 3, 1888, pp. 119–133. See also Emmons, Cross, and Eldridge.

Dana, J. D. Manual of Geology, 4th ed., New York, 1894, pp. 846–847.

Eldridge, G. H. On some stratigraphical and structural features of the country about Denver, Colorado. Proc. Colorado Sci. Soc., vol. 3, 1888, pp. 86–118. See also Emmons, Cross, and Eldridge.

Emmons, S. F., Cross, W., and **Eldridge, G. H.** Geology of the Denver Basin. Mon. U. S. Geol. Survey, vol. 27, 1896.

Fürbringer, Max. Zur vergleichenden Anatomie des Brustschulterapparates und der Schultermuskeln; iv Teil. Jenaische Zeitschr. Naturwiss., Jena, vol. 34, 1900, p. 351.

Gilmore, C. W. The mounted skeleton of *Triceratops prorsus*. Proc. U. S. Nat. Mus., vol. 29, 1905, pp. 433–435.

Gilmore, C. W. Notes on some recent additions to the exhibition series of vertebrate fossils. Proc. U. S. Nat. Mus., vol. 30, 1906, pp. 608–610.

Hatcher, J. B. The Ceratops beds of Converse County, Wyoming. Am. Jour. Sci., 3d ser., vol. 45, 1893, pp. 135–144.

Hatcher, J. B. Some localities for Laramie mammals and horned dinosaurs. Am. Naturalist, vol. 30, 1896, pp. 112–120.

Hatcher, J. B. The genera and species of the Trachodontidæ (Hadrosauridæ, Claosauridæ) Marsh. Annals Carnegie Mus., vol. 1, 1902, pp. 377–386.

Hatcher, J. B. Two new Ceratopsia from the Laramie of Converse County, Wyo. Am. Jour. Sci., 4th ser., vol. 20, 1905, pp. 413–419.

Hatcher, J. B., T. W. Stanton and. See Stanton and Hatcher.

Hay, O. P. On some recent literature bearing on the Laramie formation. Am. Geologist, vol. 32, 1903, pp. 115–120.

Hutchinson, H. N. Extinct Monsters. New York, 1893, pp. 105–108.

Lambe, L. M. On reptilian remains from the Cretaceous of northwestern Canada. Ottawa Naturalist, vol. 13, 1899, pp. 68–70.

Lambe, L. M. Sum. Rept. Geol. Surv. Dept. Canada for the year 1898, 1899, pp. 186–187.

Lambe, L. M., Osborn, H. F., and. On Vertebrata of the Mid-Cretaceous of the Northwest Territory. 2. New genera and species from the Belly River series. Geol. Surv. Canada, Contr. Can. Palæontology, vol. 3 (quarto), part 2, 1902, pp. 57–69.

Lambe, L. M. On the squamoso-parietal crest of two species of horned dinosaurs from the Cretaceous of Alberta. Ottawa Naturalist, vol. 18, 1904, pp. 81–84.

Lambe, L. M. On the squamoso-parietal crest of the horned dinosaurs *Centrosaurus apertus* and *Monoclonius canadensis* from the Cretaceous of Alberta. Trans. Roy. Soc. Canada (2), vol. 10, sec. 4, 1904, pp. 3–10.

Lambe, L. M. Progress of vertebrate palæontology in Canada. Trans. Roy. Soc. Canada (2), vol. 10, sec. 4, 1904, pp. 23–24.

Lee, J. E. Notice of saurian dermal plates from the Wealden of the Isle of Wight. Ann. and Mag. Nat. Hist., vol. 11, 1843, p. 5.

Leidy, J. Notices of remains of extinct reptiles and fishes discovered by Dr. F. V. Hayden in the badlands of the Judith River, Nebraska Territory. Proc. Acad. Nat. Sci. Phila., vol. 8, 1856, pp. 72–73.

Leidy, J. Extinct Vertebrata from the Judith River and Great Lignite formations of Nebraska. Trans. Am. Phil. Soc., 2d ser., vol. 11, 1859, pp. 139–154.

Lesquereux, L. Age of the North American Lignite. Ann. Rept. U. S. Geol. and Geog. Surv. Terr. for 1873, 1873, pp. 367–378.

Lucas, F. A. Animals of the Past. New York, 1901, pp. 100–104, 121–126.

Lucas, F. A. The dinosaurs, or terrible lizards. Ann. Rept. Smithsonian Inst. for 1901, 1902, pp. 641–646.

Lucas, F. A. Constructing an extinct monster from fossil remains. [*Triceratops*.] Sci. Am., vol. 86, 1902, p. 43.

Lull, R. S. Skull of *Triceratops serratus*. Bull. Am. Mus. Nat. Hist., vol. 19, 1903, art. xxx, pp. 685–695.

Lull, R. S. [Editorial notes on Two new Ceratopsia from the Laramie of Converse County, Wyo.] Am. Jour. Sci., 4th ser., vol. 20, 1905, pp. 413, 418–419.

Lull, R. S. Restoration of *Diceratops*. Am. Jour. Sci., 4th ser., vol. 20, 1905, pp. 420–422.

Lull, R. S. A new name for the dinosaurian genus *Ceratops*. Am. Jour. Sci., 4th ser., vol. 21, 1906, p. 144.

Lydekker, R. On a peculiar horn-like dinosaurian bone from the Wealden. Quart. Jour. Geol. Soc. London, 1890, pp. 185–186.

Lydekker, R. Some recent restorations of dinosaurs. Nature, vol. 48, 1893, p. 304.

Lydekker, R., H. A. Nicholson and. See Nicholson and Lydekker.

Marsh, O. C. Notice of some new fossil mammals. Am. Jour. Sci., 3d ser., vol. 34, 1887, pp. 323–324.

Marsh, O. C. A new family of horned Dinosauria from the Cretaceous. Am. Jour. Sci., 3d ser., vol. 36, 1888, pp. 477–478.

Marsh, O. C. Notice of new American dinosaurs. Am. Jour. Sci., 3d ser., vol. 37, 1889, pp. 334–336.

Marsh, O. C. Notice of gigantic horned Dinosauria from the Cretaceous. Am. Jour. Sci., 3d ser., vol. 38, 1889, pp. 173–175.

Marsh, O. C. Skull of the gigantic Ceratopsidæ. Am. Jour. Sci., 3d ser., vol. 38, 1889, pp. 501–506.

Marsh, O. C. Description of new dinosaurian reptiles. Am. Jour. Sci., 3d ser., vol. 39, 1890, pp. 81–83.

Marsh, O. C. Additional characters of the Ceratopsidæ, with notice of new Cretaceous dinosaurs. Am. Jour. Sci., 3d ser., vol. 39, 1890, pp. 418–426.

Marsh, O. C. The gigantic Ceratopsidæ, or horned dinosaurs, of North America. Am. Jour. Sci., 3d ser., vol. 41, 1891, pp. 167–178.

Marsh, O. C. Restoration of *Triceratops* [and *Brontosaurus*]. Am. Jour. Sci., 3d ser., vol. 41, 1891, pp. 339–341.

Marsh, O. C. Restoration of *Stegosaurus*. Am. Jour. Sci., 3d ser., vol. 42, 1891, p. 181.

Marsh, O. C. Notice of new vertebrate fossils. Am. Jour. Sci., 3d ser., vol. 42, 1891, pp. 265–267.

Marsh, O. C. On the gigantic Ceratopsidæ (or horned lizards) of North America. Rept. Brit. Assoc. Adv. Sci., 60th meeting, Leeds, 1890, 1891, pp. 793–795.

Marsh, O. C. The skull of *Torosaurus*. Am. Jour. Sci., 3d ser., vol. 43, 1892, pp. 81–84.

Marsh, O. C. Restorations of *Claosaurus* and *Ceratosaurus*. Am. Jour. Sci., 3d ser., vol. 44, 1892, pp. 343–346.

Marsh, O. C. Some recent restorations of dinosaurs. Nature, vol. 48, 1893, pp. 437–438.

Marsh, O. C. Restoration of *Camptosaurus*. Am. Jour. Sci., 3d ser., vol. 47, 1894, p. 245.

Marsh, O. C. The typical Ornithopoda of the American Jurassic. Am. Jour. Sci., 3d ser., vol. 48, 1894, p. 90.

Marsh, O. C. Restoration of some European dinosaurs, with suggestions as to their place among the Reptilia. Am. Jour. Sci., 3d ser., vol. 50, 1895, pp. 407–412.

Marsh, O. C. On the affinities and classification of the dinosaurian reptiles. Am. Jour. Sci., 3d ser., vol. 50, 1895, pp. 483–498.

Marsh, O. C. Dinosaurs of North America. Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 1, 1896, pp. 237–244.

Marsh, O. C. Vertebrate fossils of the Denver Basin. Mon. U. S. Geol. Survey, vol. 27, 1897, pp. 509–516, 527.

Marsh, O. C. New species of Ceratopsia. Am. Jour. Sci., 4th ser., vol. 6, 1898, p. 92.

Matthew, W. D. The arboreal ancestry of the Mammalia. Am. Naturalist, vol. 38, 1904, p. 816.

Nicholson, H. A., and **Lydekker, R.** Manual of Paleontology, 3d ed. Edinburgh, 1889, vol. 2, p. 1163.

Nopcsa, F. Baron, Földtani Közlöny, Budapest, 1901, vol. 31, p. 270.

Nopcsa, F. Baron, Ueber *Stegoceras* und *Stereocephalus*. Centralblatt für Mineralogie, 1903, p. 266.

Osborn, H. F. Fossil mammals of the upper Cretaceous beds. Bull. Am. Mus. Nat. Hist., vol. 5, 1893, p. 326.

Osborn, H. F. Models of extinct vertebrates. Science, new ser., vol. 7, 1898, pp. 842–844.

Osborn, H. F. Casts, models, photographs, and restorations of fossil vertebrates. Am. Mus. Nat. Hist., 1898.

Osborn, H. F., and **Lambe, L. M.** On the Vertebrata of the Mid-Cretaceous of the Northwest Territory. 1. Distinctive characters of the Mid-Cretaceous fauna. Geol. Survey Canada, Contr. Canadian Palæontology, vol. 3 (quarto), 1902, pt. 2, pp. 9, 14–15, 19–21.

Seeley, H. G. The reptile fauna of the Gosau formation. Quart. Jour. Geol. Soc. London, vol. 37, 1881, pp. 620, 637–667.

Selwin, A. R. C., and **Dawson, G. M.** Descriptive sketch of the physical geography and geology of the Dominion of Canada. Montreal, 1884, p. 40.

Stanton, T. W., and **Knowlton, F. H.** Stratigraphy and paleontology of the Laramie and related formations in Wyoming. Bull. Geol. Soc. America, vol. 7, 1898, pp. 143, 155.

Stanton, T. W. The stratigraphic position of the Judith River beds. Science, new ser., vol. 16, 1902, pp. 1031–1032.

Stanton, T. W. [Note in J. B. Hatcher's "An attempt to correlate the marine with the nonmarine formations of the Middle West."] Proc. Am. Philos. Soc., vol. 43, 1904, p. 364.

Stanton, T. W., and **Hatcher, J. B.** Geology and paleontology of the Judith River beds. Bull. U. S. Geol. Survey No. 257, 1905.

Steinman, G., und **Döderlein, L.** Elemente der Paläontologie. Leipzig, 1890, p. 665.

Walcott, C. D. Correspondence relating to collection of vertebrate fossils made by the late Prof. O. C. Marsh. Science, new ser., vol. 11, 1900, p. 23.

White, C. A. Section of Laramie strata at Black Buttes station. Ann. Rept. U. S. Geol. Surv. Terr. for 1877, pp. 222–223.

White, C. A. (Bibliographical sketch of Dr. F. V. Hayden.) National Academy of Sciences, Biographical Memoirs, vol. 3, pp. 399–400.

Williston, S. W. The Laramie Cretaceous of Wyoming. Science, new ser., vol. 16, 1902, p. 952.

Woodward, A. S. Outlines of Vertebrate Palæontology. Cambridge, 1898, pp. 213–216.

Zittel, K. A. von. Handbuch der Palaeontologie. Munich and Leipzig, 1887–1890, vol. 3, pp. 749–754.

Zittel, K. A. von. Text-book of Palæontology. English translation by C. R. Eastman. London, vol. 2, 1902, pp. 243–245.